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CONTENTS

Techniques for the Study of Learning in Animals: Analysis and Classification ..... M. E. BITTERMAN 81

The Study of Persistence ..... N. T. FEATHER 94

Cognitive Learning in Infancy and Early Childhood . WILLIAM FOWLER 116

Radiation Research in Psychology: An Analysis of Techniques in Maze Experimentation ..... SYLVAN J. KAPLAN 153

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Psychological Bulletin

TECHNIQUES FOR THE STUDY OF LEARNING IN ANIMALS: ANALYSIS AND CLASSIFICATION[1]

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Although many different techniques for the study of learning in animals have been developed in the 60 years or so since the problem of animal intelligence first was brought into the laboratory, their interrelations never have been carefully defined. Crude dichotomies have been proposed—"respondent conditioning" versus "operant conditioning" by Skinner (1935, 1937), "classical conditioning" versus "instrumental conditioning" by Hilgard and Marquis (1940)—and, more recently, a trichotomy—"classical conditioning" versus "instrumental conditioning" versus "selective learning" by Spence (1956)—but the diversity of method is too great to be encompassed in any such one-way analysis. While certain differences among the techniques to be classified *must* be ignored if the number of categories is to be smaller than the number of techniques, the quest for parsimony seems to have been carried too far.

Classification is not merely a matter of taste. When one can find no objective basis for evaluating the conviction that a given difference in technique should be stressed or that another safely may be disregarded, it is only because the proper experiments have not been performed. Consider, for example, the question of whether the difference between flexion conditioning with avoidable as compared with unavoidable shock should be reflected in a classification of techniques. The answer is "Yes" for Hilgard and Marquis, who emphasize the contingency of reinforcement on response. They classify flexion conditioning as "classical" when shock is unavoidable and as "instrumental" when shock is avoidable. The answer is "No" for Spence, who emphasizes the degree of control afforded the experimenter over the appearance of the response to be learned. Ignoring the contingency of shock upon failure of response to the CS, Spence treats avoidance conditioning as a special case of classical conditioning in which the pattern of reinforcement gradually shifts from consistent to intermittent. Such a disagreement surely need not remain long in the realm of opinion. One has only to compare the behavior of an animal trained with avoidable shock and that of a control animal trained with shock that is unavoid-

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able but simply withheld on whichever trials the first animal avoids; if response contingency is unimportant, the course of learning in the two animals should be the same.

In general, a classification of techniques may be treated as the expression of a set of hypotheses about the functional significance of differences in technique—a distinction between two techniques as an assertion that they yield results which differ in some fundamental respect, and a failure to distinguish between two techniques as an assertion that they may be used interchangeably in the analysis of learning. This is not to say that a classification may not be preferred on historical, or on pedagogical, or even on esthetic grounds, but only that a functional interpretation is available which provides a basis for empirical evaluation. Methodological and functional considerations have, in fact, been linked rather closely in the past. Methodological distinctions have been taken as points of departure for dual-process analyses of learning, while strivings for a unitary conception have been reflected in the blurring of methodological distinctions. One may even point to experiments designed explicitly to provide a functional comparison of different methods (Youtz, 1938a, 1938b, 1939), although the empirical study of methodological interrelations certainly has not been carried very far.

Functional considerations play a central role in the classification to be offered here, which grows out of a program of comparative research (Bitterman, 1960). The first step in the program is to assess the phyletic generality of certain theoretically significant phenomena of learning which have been established in work with the rat (hitherto the principal subject of research on learning), and to that end a variety of simple animals must be studied under conditions analogous to those which have been used for the study of the rat; but what are "analogous" conditions? Clearly, the answer to this question requires some hypotheses about the essential properties of the various techniques which have been used for the rat. As will later be indicated, the comparative enterprise not only motivates further methodological analysis but constitutes a new source of data in terms of which the outcome may be evaluated.

Thorndikian Situations

It seems reasonable to begin the analysis with a set of closely interrelated techniques which date back to the turn of the century and which have yielded most of the information on which contemporary conceptions of animal learning are based. The adjective *Thorndikian* is appropriate both because of Thorndike's pioneering role in their development and because their operation is predicated on an empirical law of effect. Familiar examples are the problem box and the maze. In each of these situations, traditionally, the experimenter sets out to change behavior by manipulating its consequences, that is, by arranging a contingency between some motivationally significant state of affairs ("reinforcement") and the behavior in question. Thus, pulling a loop in a problem box or turning to the left in a T maze may be encouraged with food or discouraged with shock. Indeed, the motivational significance of any event may be assessed in terms of its effect on the response which produces it in such a situation. An event that facilitates the occurrence of a response upon which it is contingent is called a *reward;* an event that has the op-

posite effect is called a *punishment;* while an event that produces no measurable change in behavior is motivationally insignificant or neutral. An aversive stimulus is one whose onset is punishing, and in what is called *escape training* the offset of such a stimulus serves as a reward.

Unitary and Choice Situations

An important distinction between two main types of Thorndikian situation may be illustrated by a comparison of the problem box and the maze. In both these apparatuses, the animal is afforded numerous possibilities for action, one of which the experimenter chooses to reward. The main difference between them has to do with the treatment of irrelevant responses. In work with the problem box, the experimenter may take some qualitative notice of the variety of fruitless activities which appear, but his interest is centered on the rewarded response and the readiness with which it comes to expression. The basic datum is time. In the maze, by contrast, the unrewarded behavior of the animal is structured more clearly; certain major alternatives to correct response are delineated, and the interest of the experimenter is centered on their decline and disappearance. The basic datum is error. Time may be recorded, but it does not as clearly reflect progress in the choice among alternative courses of action, the aspect of selective learning which the maze is so well suited to display.

The designation *unitary* Thorndikian situation (or T-1 situation) will be used here for the problem box and for any other Thorndikian situation in which but a single course of action is defined and the readiness with which it comes to expression is measured. The designation Thorndikian *choice* situation (or T-2 situation) will be used for the maze and for any other Thorndikian situation in which two or more incompatible courses of action are defined and choice among them is studied. The nature of the responses delineated and the general properties of the environments in which they appear are ignored in this classification. Thus, a problem box which offers a choice of manipulanda is classed with the maze as a T-2 situation, while the runway is classed as a T-1 situation despite its structural resemblance to the maze. The runway may, of course, provide a measure of error, as in the early works of Hicks (1911), who plotted the learning of a culless maze in terms of retracing, while the potentialities of the maze for the study of choice may be ignored, as in the early work of Thorndike (1898), who, measuring only time, used the maze as though it were just another problem box. In such cases, the classification is based on the use to which the apparatus actually is put in a given experiment. For the most part, however, contradictions between potentiality and use are rare. An investigator interested in choice among alternative courses of action is not likely to use a runway, nor, unless he is interested specifically in choice among alternative courses of action, is he likely (today) to use a maze.

Both T-1 and T-2 situations may be "chained." The most common example of a chained T-2 situation is the maze of many choice-points, once very much the mode, but rarely encountered today, perhaps because of the conviction, expressed by Lashley (1918), that the single-unit maze is quite as sensitive as the multiple-unit maze to the effects of significant variables and much less costly in time and effort. (The two

kinds of apparatus are not, of course, fully equivalent; certain problems—such as that of correction versus non-correction, first studied by Lashley—arise only when the number of choice points is reduced to one, while other problems—such as that of serial order—disappear.) Chained T-1 situations never have been widely used. An example may be found in a string of problem boxes, each presenting one manipulandum, with the first giving access to the second, the second to the third, and so on, until the reward finally is attained (Herbert & Arnold, 1947). For certain purposes, conceivably, mixed chains (composed both of T-1 and of T-2 units) might be used.

Generalized and Discriminative Situations

Each of the two types of Thorndikian situation already distinguished—*unitary* and *choice*—may occur in *discriminative* as well as in *generalized* form. This new distinction, which is orthogonal to the first, will be conveyed by adding the letters g (for generalized) and d (for discriminative) to the symbols for unitary and choice: T-1g, T-1d, T-2g, T-2d. In a discriminative problem, the experimental environment is varied systematically from trial to trial, and with it the consequences of response, the capacity of the animal to discriminate the change being inferred from a corresponding variation in behavior. In a generalized problem, there may be some variation in the experimental environment from trial to trial (intentional or unintentional), and there may be some variation in the consequences of response (as in work on partial reinforcement), but there is (by definition) no correlation between the two kinds of change, and hence there is no objective basis for systematic variation in behavior.

In the simplest T-1d case, a single defined response is rewarded under one set of conditions but not rewarded (or punished) under another set of conditions, and the readiness with which the response comes to expression under the two conditions is compared. For example, response in a single-window jumping apparatus is rewarded when a white card is displayed but punished when the card displayed is black (Solomon, 1943). Performance in a T-1d problem may be expressed in terms of "error," but a temporal criterion is implied. For example, in an early experiment by Thorndike (1898), cats were fed for climbing to the top of their cage in response to the words "I must feed those cats," but not for making the same response to the words "Tomorrow is Tuesday," an error being recorded whenever they climbed up (promptly) to the second phrase or failed (in a reasonable period of time) to climb up in response to the first. Similarly, Grice (1949), working with another T-1d situation, computed the median response time for a series of trials and counted as an error any response to the negative stimulus faster than the median or any response to the positive stimulus slower than the median. A clear distinction should be made between error thus defined and erroneous choice in a T-2d situation.

In a T-2d problem, two or more alternative responses are defined—two in the simplest case. One of the responses is rewarded and the second unrewarded (or punished) under a given set of conditions, while the consequences of the two courses of action are reversed under another set of conditions, and erroneous choices are counted. For example, in a conventional jumping apparatus, a jump to the right window is rewarded when the card in the right window is

white and the card in the left window is black, but a jump to the left window is rewarded when the positions of the two cards are interchanged; or, in the same apparatus, response to the right window is rewarded when two white cards are displayed, but response to the left window is rewarded when two black cards are displayed. (Problems of the first kind have been termed "simultaneous" while problems of the second kind have been termed "successive," an adjective applied as well to T-1d problems; considerable confusion has resulted from the failure to distinguish between T-1d and successive T-2d problems.) The so-called "higher order" discriminations—oddity, matching-from-sample, and multiple choice—also may be classified as T-2d problems, although they seem to make demands which go far beyond those of the simpler problems first exemplified. The T-1d and T-2d categories actually are rather coarse ones which themselves invite careful analysis and subdivision.

Like T-2g situations, T-2d situations may be "chained"—as when an animal is required to make a series of choices based on brightness before the reward is attained (Stone, 1928). Meaningful T-1d chains also are possible, although no instance of such a chain is to be found in the literature. For example, response to a manipulandum in one unit gives immediate access to the next unit when the positive stimulus is present; when the negative stimulus is present, access to the next unit is given after a predetermined period of time whether or not the animal responds.

Discrete and Continuous Situations

There has been little clarity on the relation of Skinner's technique to other techniques for the study of learning in animals. It has been asserted by Woodworth (1938), for example, that the Skinner box "bridges the gap" between the problem box and the classical conditioning situation, and a similar view is met again in Spence (1956), who places the Skinner box on a continuum at a point intermediate between the methods of Thorndike and Pavlov; but the notion of continuity is difficult to justify. Skinner (1935, 1937) certainly has succeeded very well in drawing a sharp line between his method and that of Pavlov on the basis of criteria which fail to distinguish his method from that of Thorndike.

Skinnerian situations are Thorndikian situations as the term is defined here. The original Skinner box differs from the older problem box only in that it delivers food to the response compartment (instead of admitting the animal to a separate feeding compartment) when the defined response is made, a feature which eliminates handling of the animal between trials. Equipped with a retractable lever, which is introduced to begin each trial and withdrawn after response, the Skinner box may be used in exactly the same manner as the older problem box; in fact, a retractable manipulandum which delivered food to the responding animal was developed for the monkey by Thorndike himself (1901). Skinner (1932), of course, has preferred to use his apparatus as a "repeating" problem box—his own adjective—inverting the traditional measure of performance, and substituting for time per response on discrete trials number of responses per unit time (rate of response) to a continuously available lever. Either way, a Skinner box containing one lever may be classified as a T-1 situation. A single response is delineated, its consequences are

manipulated, and the readiness with which it comes to expression is measured. With two levers and the study of choice, the Skinner box becomes a T-2 situation.

It seems reasonable, nevertheless, to make a formal distinction between Thorndikian situations in which latencies or choices are measured in discrete trials and their Skinnerian counterparts in which rates of response are measured under conditions of continuous opportunity to respond. Situations of the first kind will be designated as *discrete*, while those of the second kind will be designated as ***continuous***, and for symbolic purposes the subscripts d (for discrete) or c (for continuous) will be added to the T for Thorndikian, as, for example, in T_d-2g (discrete, choice, generalized) or in T_c-1d (continuous, unitary, discriminative). The discrete-continuous distinction reflects the hypothesis that rate of response, despite its close mathematical relation to latency, has a functional significance which is to a certain extent unique, and some interesting evidence for this view comes from comparative studies of the effect of inconsistent reinforcement on resistance to extinction. In the rat, discrete and continuous techniques both give the so-called paradoxical effect (greater resistance to extinction after inconsistent than after consistent reinforcement). In the fish, initial resistance to extinction is greater after consistent reinforcement in the discrete case (Longo & Bitterman, 1960; Wodinsky & Bitterman, 1959, 1960); but some as yet unpublished data show greater resistance to extinction after inconsistent reinforcement in the continuous case. Whether the difference in outcome may be traced to a difference in the functional properties of the two techniques, or whether it is a product of certain parametric differences between the two sets of experiments, remains to be determined. The matter is introduced here only to suggest the possibility that techniques which are functionally equivalent for one species may not be so for others. In this connection it is worth noting, perhaps, that the potentialities of the rate measure seem to be realized fully only when inconsistency of reinforcement is introduced.

A General Definition of Thorndikian Situations

In each of the Thorndikian situations considered thus far, a change in behavior is measured which springs from a contingency between some defined response and some motivationally significant state of affairs. Experiments on latent learning suggest, however, that a Thorndikian situation may be characterized without reference either to the actual occurrence of change in behavior or to the motivational significance of the consequences of response. In the T-1 case, an investigator may set out deliberately to minimize the motivational significance of the consequences of response in an effort to minimize the extent of change in behavior. For example, a hungry rat is trained in a runway which leads to an empty end box or to one which contains only water. To arrange a set of end-box conditions which are entirely without motivational significance is not, of course, always very easy, but it can be done (Gonzalez & Diamond, 1960). In the T-2 case, the consequences of alternative responses, whether motivationally significant or not, may be balanced in an effort to forestall the development of a preference for one or the other response. For example, a hungry rat is run in a simple T maze with both end boxes empty, or one empty and the other containing only water, or one containing food

and the other both food and water; or a rat that is both hungry and thirsty is run in a T maze with one end box containing food and the other containing water. Such situations are intended merely to provide occasions for learning whose effects are estimated in later tests. The tests always involve a change in the motivational significance of the consequences of response: for example, food is added to a previously empty end box; or the end box is associated with food in direct feedings; or the prevailing condition of deprivation is altered, and with it the relevance of previously encountered incentives. Nevertheless, despite the careful attention which must be paid to motivational significance in evaluating the outcome of exposure to a Thorndikian situation, the situation itself may be defined without reference to motivational significance. What is essential only is *a contingency of some specified event or circumstance on some measurable bit of behavior*—a contingency arranged by an investigator who is interested in studying its effects on the animal.[2]

[2] No treatment of Thorndikian techniques would be complete without some mention of a set of situations closely related to the problem box (calling for string-pulling, rake-wielding, box-stacking, and the like) which figured prominently in the work of certain of Thorndike's critics, beginning with Hobhouse (1901), who did not think that Thorndike's apparatus provided a representative picture of animal intelligence. Designed to be fully "surveyable" (to conceal nothing from the animal) and, although simple in principle, to render "chance" solutions unlikely, these (Hobhousian) situations present Thorndikian contingencies of a rather loose sort and *may* be used, like Thorndike's problem boxes, to study the way in which the experience of such contingencies affect subsequent behavior. Their principal use, however, has been in inquiries into the ability of animals to discover appropriate modes of behavior in advance of reinforcement—that is, in quests for evidence of "productive" or "inferential" as contrasted with "reproductive" or learned solutions.

Pavlovian Situations

Well before Pavlov's experiments on conditioning became widely known, other investigators were led quite independently, by an interest in associative learning, to experiments of essentially the same kind. As far back as the turn of the century, a distinction was made between what was called "trial-and-error" or "selective learning"—the modification of behavior as a function of its consequences—and what was called "association of stimuli" or "substitution"—the acquisition by one stimulus of some of the behavioral properties of a second stimulus as a function of the pairing of the two stimuli. Primarily concerned though he was with selective learning, Thorndike (1898) himself made use of paired stimulation; when a verbal statement such as "I must feed those cats" was followed regularly by the presentation of food, he reported, the words alone would bring the animals to the feeding place. It seems fitting nonetheless—in view of the scope of Pavlov's (1927) contribution—that the method should bear his name.

In the traditional Pavlovian experiment, as in the traditional Thorndikian experiment, the behavior of the animal is altered by the introduction of some motivationally significant stimulus such as food or shock ("reinforcement"), but there are important differences. In a Thorndikian experiment, reinforcement is contingent on response; doing one thing leads to food or to shock, doing another does not. In a Pavlovian experiment, reinforcement is scheduled without regard to response; the experimenter does not set out to mold behavior in some predetermined fashion, but only to study the way in which the functional properties of one stimulus are altered by virtue of its contiguity with another. Because their introduction is not

contingent on the animal's behavior. Pavlovian reinforcements cannot be treated as rewards or punishments in any meaningful manner, nor can rewards and punishments be distinguished in a Pavlovian experiment. Another difference between the two techniques is worth noting. In a Thorndikian experiment, the choice of the behavior which is to serve as the index of learning is independent of the choice of reinforcement; any of a large variety of responses which the animal is likely to make may be encouraged with food or discouraged with shock. In a Pavlovian experiment, the choice of reinforcement restricts the choice of a behavioral indicator; while the conditioned and unconditioned responses are not always (as Pavlov thought) identical, the investigator must be guided in his search for evidence of learning by the functional properties of the reinforcing stimulus. Sharp as the distinction may be between the traditional Thorndikian and Pavlovian procedures, it has been ignored very often by theorists preoccupied with the task of deriving all of the data of learning from the operation of a single process. Pavlov himself claimed, of course, that all instances of learning could be analyzed as instances of conditioning, although Thorndike, committed as he was to the generality of the law of effect, never was satisfied that Pavlov's procedure could be cast in the same mold as his own.

Coordinate with the unitary Thorndikian (or T-1) situation is the unitary Pavlovian (or P-1) situation, in which the tendency for a CS to produce some defined effect is measured in terms of latency or magnitude. The defined effect may be a response which is reflexly elicited by the US, as in the salivary conditioning experiment, or something quite different, as when the rate of fixed-interval responding in a Skinnerian situation is depressed by shock and by a stimulus paired with shock (Estes & Skinner, 1941). A P-1 situation may be generalized (P-1g) or discriminative (P-1d); in the discriminative case, the CS is varied systematically from trial to trial and with it the likelihood that the US will be presented (as, for example, when a bright light always is followed by food but a dim light never is). With two unconditioned stimuli, each eliciting a different response, it is possible to set up a P-2 situation, the Pavlovian analogue of the Thorndikian choice situation. (A T-2 situation may be constituted with but a single reinforcer, which is another interesting difference between Pavlovian and Thorndikian techniques.) The discriminative (P-2d) case is perhaps the easier to conceive than the generalized (P-2g). For example, one CS is paired with acid introduced into the mouth of a dog, while another CS is paired with meat-powder (Pavlov, 1927). The P-2g case must involve some inconsistency of reinforcement (which is, or course, not true of T-2g). For example, a CS is paired with shock to the right forelimb on a random 75% of trials and with shock to the left forelimb on the remaining 25% of trials. This is the Pavlovian analogue of a kind of T-2 situation in which there has been much interest of late. For example, a right turn at the choice point of a maze leads to food on a random 75% of trials while a left turn leads to food on the remaining 25% of trials (Brunswik, 1939).

The discrete-continuous dichotomy, which was developed in the analysis of Thorndikian procedures, seems to have no Pavlovian parallel; Pavlovian training is an affair of discrete trials. Nor does the notion

of "chaining" have any application to Pavlovian procedures.

A Pavlovian situation, like a Thorndikian situation, may serve merely as an occasion for learning whose effects are measured in subsequent tests. One such case, well known to Pavlov, is that in which the presentation of CS and US is strictly simultaneous; only when the training procedure is altered can the effects of pairing be assessed. A second is that of "sensory preconditioning"—conceived originally by Thorndike (1898) himself as a check on the existence of "representations"—which is analogous to the Thorndikian experiment with consequences of response which are lacking in motivational significance; neutral stimuli are paired, then one is given some behavioral property, and the effects of the pairing are estimated from response to the other. A third case is that in which attention is centered on the acquisition, not of response-eliciting properties, but of rewarding properties (Williams, 1929); for example, an animal is fed repeatedly in a distinctive box (that is, box and food are paired), after which access to the empty box is made contingent upon response in a Thorndikian situation. In one variety of experiment which has considerable theoretical importance, the order of these experiences is reversed; the contingency of access to the empty box upon some response is displayed, after which the animal is fed in the box, and the effect on response is measured (Gonzalez & Diamond, 1960). In general, then, a Pavlovian situation may be defined without reference either to the occurrence in that situation of any particular kind of behavioral change, or to the functional properties of the stimuli which are paired. What is essential only is *a sequence or conjunction of stimuli whose contiguity is independent of the animal's response.*

Avoidance Situations

The only learning situations which cannot be classified unequivocally as Pavlovian or Thorndikian are those which involve the avoidance of aversive stimulation. In them, Pavlovian and Thorndikian features are closely intertwined. On the one hand, a neutral stimulus is paired with an aversive stimulus, thereby acquiring certain arousing properties. The pairing is not, on the other hand, entirely independent of the animal's behavior—the aversive stimulus is introduced only if the CS fails to elicit some defined response, whose likelihood of occurrence (low at the outset) the pairing serves to increase. This contingency of reinforcement on response is not displayed on the very first trial, as it is in a pure Thorndikian situation. In avoidance training, the contingency is a negative one, which (since the mere possibility of avoidance cannot influence the animal) does not become manifest until the Pavlovian procedure has taken effect.

There is another Thorndikian contingency which operates in some (though not in all) avoidance situations, this one making itself felt from the very first trial: termination of the aversive stimulus may be contingent on some defined response, often—but not always—the same response as that which avoids the aversive stimulus. In flexion conditioning, when shock to the limb is administered through a grid on which the limb of the animal rests, and when the scheduled duration of shock is substantial, flexion both escapes and avoids shock. In the shuttle box, too, the conditions of training may be such that changing compartments both escapes and avoids shock, al-

though, as Warner (1932) noted early, the response which escapes shock may be different from that which avoids it (for example, leaping over a hurdle as compared with crawling under). It is possible, of course, to set up an avoidance situation in which there is no escape at all. In flexion conditioning, shock may be administered through a bracelet attached to the limb, and a control circuit so arranged that the CR will forestall the shock but the UR will not alter its scheduled duration. In the shuttle box, the shock may be very brief, terminating quite independently of any response the animal may make to it (Hunter, 1935). Even without escape, however, there remains the contingency of aversive stimulation on failure of response to the CS, an essential feature of avoidance training which distinguishes it from Pavlovian training, while the paired stimulation which is responsible for the emergence of response to the CS distinguishes it from Thorndikian training. Avoidance training seems to require a major category of its own.

In its most common use, the shuttle box may be classified as an A_d-1g situation (A for avoidance); a single course of action is defined, and its latency is measured in discrete trials without systematic variation in sensory conditions. The corresponding discriminative (A_d-1d) situation also may be generated in the shuttle box; for example, a bright light is followed by shock unless the defined response is made, but a dim light never is followed by shock. In such a situation, it may be noted, discrimination can progress only as the animal fails to respond to the dim light, since the consequences of response to the two lights are identical. (In a T-1d situation, by contrast, the consequences of response to the stimuli to be discriminated are different, and discrimination therefore is facilitated by response to the negative stimulus; in a P-1d situation, discrimination may progress quite independently of response.)

Choice among alternative courses of action also may be studied in avoidance situations. Suppose, for example, that shock from a grid in the floor of a T maze is scheduled x seconds after an animal is placed in the starting box. In the generalized (A_d-2g) case, shock is avoided by prompt entrance into the end box on the right, but not by entrance into the end box on the left. In the discriminative (A_d-2d) case, a turn to the right avoids shock when the stem of the maze is black, while a turn to the left avoids shock when the stem is white. Two unconditioned stimuli are not required to generate an A-2 situation as they are to generate a P-2 situation, but two unconditioned stimuli may be used. For example, one signal is followed by avoidable shock to the right limb, while a second is followed by avoidable shock to the left limb (James, 1947).

The discrete-continuous dichotomy developed in the analysis of Thorndikian situations is applicable also to avoidance training. An A_o-1g situation may be constituted in a modified Skinner box or a shuttle box. In a design developed by Sidman (1953), no exteroceptive warning signal is used, but shock is scheduled every x seconds by a clock which the defined response resets. (The lack of an exteroceptive signal does not, of course, subvert the definition of avoidance training as originating in a quasi-Pavlovian contiguity of stimuli; as Pavlov himself showed, internal processes correlated with the passage of time since the occurrence of a specified event may be cast in the role of CS). In the corresponding

discriminative (A_e-1d) case, the clock which schedules shock runs only under one of two sensory conditions. Avoidance situations of the continuous type which do involve exteroceptive signaling also are feasible. In the A_e-1g case, for example, shock from a grid in the floor of a Skinner box is scheduled x seconds after the onset of a light and avoided by response on a variable-ratio schedule. A_e-2 situations, both generalized and discriminative, may be generated when alternative courses of action are defined.

Like Thorndikian situations, avoidance situations may be chained. Just as an animal may learn to run a simple T maze under threat of shock, so it may learn to run a multiple T maze. An example of chaining in an avoidance situation of the continuous type is the following: with the onset of the CS, response to one manipulandum is followed, on a variable-ratio schedule, by access to a second manipulandum, response to which, again on a variable-ratio schedule, terminates the CS and avoids shock.

Although the term implies threat of an aversive condition which the animal learns to forestall, avoidance training, like Thorndikian and Pavlovian training, may be characterized without reference to the nature of the stimuli employed or to the occurrence of behavioral change. It would be possible, for example, to train an animal with some neutral stimulus rather than shock in a shuttle box designed to produce a substantial frequency of spontaneous crossing, and then to test for learning after the neutral stimulus has been paired with shock. Irrespective of outcome, the conception of such an experiment is sufficient to delineate what is here regarded as the essential feature of avoidance training: *a sequence of stimuli is scheduled with the occurrence of the second contingent upon the failure of the animal to make some specified response to the first.*

Terminology

While there need be no detailed comparison of the classification here proposed with earlier ones, it may be worth while, in the interest of preserving whatever compatible usages may exist, to consider how well some of the broader methodological designations which now are current will serve the needs of the new classification. Since current terminology derives from earlier classifications, the major differences in emphasis must become quite apparent in the process.

The term "conditioning" usually is used for the kind of training here called Pavlovian, but that term also is used rather widely to designate techniques which are not here classified as Pavlovian, and often as a synonym for "learning" itself. The term "classical conditioning" is closer to what is here intended by Pavlovian, although in some contexts it has a narrower meaning (suggesting a harnessed animal) and in other contexts a broader one (encompassing avoidance). Avoidance remains a useful term, but "instrumental conditioning" is too ambiguous, since it has been applied indiscriminately both to avoidance training and to pure Thorndikian training. The term "operant conditioning" is even more ambiguous; it has a narrow (Skinnerian) sense in which it is tied to a questionable distinction between "elicited" and "emitted" behavior, as well as a more general sense in which it is equivalent to instrumental conditioning. The term "selective learning" has a pure Thorndikian connotation, but it seems to designate a process of learning rather than a method of studying it.

In general, there is little to salvage in the current terminology. Specific situational designations, such as maze, problem box, and runway, continue to be useful, but the broader classificatory terms are unsuitable because they are geared to methodological dichotomy rather than to trichotomy. Even if dichotomy should in time give way to trichotomy, of course, it is likely that many of the older terms will continue to be used with altered meanings and with considerable consequent confusion. The terms for the subcategories here defined—unitary and choice situations, generalized and discriminative situations, discrete and continuous situations—fortunately do not compete with established usages and therefore create less opportunity for confusion, although it is possible that a clearer notation might be found. Reflection will show, however, that complexity of notation is to a certain extent an inevitable consequence of the amount of information to be conveyed.

It is natural that a new classification should require a new terminology, although a change in classification does not, of course, necessarily imply an advance in conception. Whether the classification here proposed represents an advance in thinking about the interrelations among learning situations cannot now be told. Classification is more, ultimately, than a matter of taste, but there is little else on which to depend at the present time. It is to be hoped that a renewed concern with problems of classification will stimulate further research on methodological interrelations.

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THE STUDY OF PERSISTENCE[1]

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The present review of studies of persistence has two main aims:

1. Of primary importance, it will consider the different approaches which have been made in the literature to the investigation of persistence with humans.

2. As a more specialized aim, it will attempt to clarify the relationship of persistence at a task to motives and expectations by considering the following two questions: How does the initial ease or difficulty of a task influence the persistence displayed by a subject in his attempt to perform the task? How do individual differences in strength of motive to achieve success (M_s) and strength of motive to avoid failure (M_{af}) influence persistence at a task?

The general paradigm of the persistence situation is that in which a person is confronted with a very difficult or insoluble task and is unrestricted in either the time or number of attempts he can work at it. He is unsuccessful at each of these attempts at the task, but can turn to an alternative activity whenever he wishes. Persistence may be measured by the total time or total trials which the person works at the task before he turns to the alternative activity. The former measure is sometimes referred to in the literature as temporal persistence, the latter measure is analogous to resistance to extinction.

Persistence may be distinguished from the performance level or effort involved in an activity and from the direction which an activity takes, but belongs with both of these as an important behavioral symptom of motivation. This distinguishing characteristic of motivated behavior has long been recognized in the literature. To cite a few examples of its widespread recognition, McDougall (1908), in his discussion of instinct, lists persistence as one of the objective features of purposive behavior; Tolman (1932), while rejecting the mentalistic teleology of McDougall's position, considers persistence-until-ends-are-attained as a basic criterion for molar, purposive behavior; Lewin (1935) discusses the persistence of tension within the regions of the person, a conception which has a crucial part in the interpretation of the research concerning rigidity, substitute activity, and interrupted tasks (cited in Lewin, 1946); and both Hull (1943) and Dollard and Miller (1950), within the context of drive theory, are concerned with the problem of continuing action. More recently Peak (1955) and Atkinson (1957) have emphasized that a theory of motivation has as one of its important aims the conceptualization of persistence in behavior; and Bindra (1959), arguing within the general framework of Hebb's concepts (1949), considers persistence as one of the defining characteristics of goal directed action. Thus, there is no lack of recognition of the importance of accounting for persistence in be-

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havior despite diversity in conceptual approaches.

The background research falls into three fairly distinct classes. The *first* class comprises studies which are concerned with persistence as a trait or uniformity in behavior. Typically, these study—by correlational techniques—relationships between persistence scores (usually in terms of time) for a variety of different types of task. In more recent research, factor analytic methods have been used in an attempt to account for the obtained correlations. The overriding interest in these studies is in consistency in behavior. Will a subject who persists at one task also tend to persist at another? Consistency, where it occurs, is assumed to allow the inference of a relatively stable personality characteristic. The role of situational factors in determining behavior tends to be ignored since the emphasis is on personality structures or traits which transcend the situation. To the extent that momentary situational influences are excluded from consideration, the trait approach commits the "organism error" (MacKinnon, 1944).

The *second* class of studies comprises those with humans which are concerned with the problem of resistance to extinction. Although they are not commonly discussed as persistence studies, the structure of the situation is to some extent similar to that employed in studies where persistence is conceived as a trait. In the trait studies a common technique is to measure the time for which the subject persists at a very difficult, effortful, or insoluble task *without success*, i.e., temporal persistence. In the extinction studies the subject typically performs a task *without reinforcement* after having been subjected to a particular type of reinforcement schedule during an acquisition series. Number of trials to extinction is taken as the measure. This similarity should not blind us to important differences between these situations. Extinction studies generally ignore the possible effect of relatively stable personality differences and focus more on the influence of situational variables, particularly differences in the pattern and amount of reinforcement in the acquisition series. In this respect they are in marked contrast to the personality oriented trait studies and, to the extent that they exclude personality differences from consideration, they commit the "situation error" (MacKinnon, 1944).

Finally, the *third* class of studies comprises those in which persistence is conceived as a motivational phenomenon. On the one hand the theory may consider persistence mainly in terms of situational parameters leaving personality variables relatively unspecified. Lewinian field theory appears to come close to this approach in its detailed analysis of factors in the psychological environment such as valences and barriers, and its relative lack of an explicit analysis of the individual. On the other hand the approach may be more thoroughly interactive, as in the theory of achievement motivation (Atkinson, 1957, 1960) which conceives of stable personality dispositions or motives in interaction with expectations and incentive values which are both situationally defined. It is this latter approach that permits clarification of the question of how persistence might be related to differences in strength of achievement related motives and initial expectation of success. Hence, more attention will be given to the experimental literature from this area and only a partial sampling of studies from the other two classes of

investigation will be presented.

The three classes of studies may be seen as falling on a continuum with personality oriented trait studies at one end, situation oriented extinction studies at the other end, and studies which consider the interaction of personality and situation between the two extremes.

Persistence Conceived as a Trait Underlying Behavior

These investigations fall into two main groups:

1. Those which investigate correlations between persistence scores for a large number of different tasks, or correlations between persistence scores and other variables such as age, intelligence, or academic success, but which do not proceed to a factor analysis. These, in general, are the early trait studies as exemplified by the classical research of Hartshorne, May, and Maller (1929). They will be designated "nonfactorial trait" investigations of persistence.

2. Those which do proceed to a factor analysis. These are designated "factorial trait" investigations of persistence.

The transition from 1 to 2 exemplifies the initial steps in the evolution towards a scientific explanation. There is progression from the concept of persistence as a property of persons, some possessing it more than others, to the attempt to classify different types of persistence. It will be argued, however, that classification is only a preliminary step, albeit a most important one, and that the factor analytic studies fail to provide an adequate conceptualization of why people differ in persistence between situations.

Nonfactorial Trait Studies

Many of these early investigations of persistence are reviewed by Ryans (1939). Perhaps the best illustration of a nonfactorial trait study is to be found in the monumental research of Hartshorne, May, and Maller (1929). In this investigation a wide variety of tasks were used, some of which were administered individually, others in a group setting. The eight persistence tests that were employed consisted of story resistance, puzzle mastery, paper and pencil puzzle solution, fatigue and boredom in mental work, hunting for hidden objects, continued standing on right foot, eating cracker and whistling, and solving a toy puzzle. The reliability coefficients were found to range from .40 to .85. Validity coefficients obtained by comparing test results with teachers' ratings of persistence were from zero to .33. The correlations between the various tests were generally low. There was low positive correlation between results of persistence tests and intelligence test scores. Some tendency was found for persistence to increase with age for the age range (9–16 years) investigated.

In common with the foregoing study, other early trait studies of persistence investigated an extensive and often bewildering variety of tasks which ranged from subjective ratings of persistence, through difficult or insoluble puzzle tasks, to measures of physical endurance. Persistence was usually measured by total time taken at the task. In addition to differences in the types of task employed one would also expect differences in the test context in which these tasks were presented, e.g., the degree to which the situation was achievement oriented, whether or not the task was administered individually or to a group. In view of these differences it is not surprising that intercorrelations of persistence scores were often low. With the increasing use of factor analytic meth-

odology it was natural for investigators to look for order in the concomitances and to go beyond the often puzzling examination of the correlation table to the statistical intricacies of factor extraction.

Factorial Trait Studies

One of the earliest factor analytic studies concerned with persistence was carried out by Webb (1915). Working within the context of a Spearman analysis, he correlated ratings and isolated a W factor which was thought to comprise component traits such as reliability, tact, and persistence of motives. Crutcher (1934) in another early factorial investigation tested London school children (age range 7–16 years) on persistence tests including card-house building, mechanical puzzle solution, addition, picture copying, and canceling A's. He found a correlation of .30 between persistence and intelligence, and a tendency for more persistent children to be slightly inclined towards introversion. When the intercorrelations between time taken on each of the various persistence tasks by his subjects were analyzed by the Spearman tetrad method, Crutcher found some evidence for a general factor. Alexander (1935) identified an X factor, which ran through school subjects but not through ability measures, as involving persistence, and this was consistent with the generally obtained positive correlation between persistence measures and school success.

Later investigations by Ryans (1938), Thornton (1939), Rethlingschafer (1942), Kremer (1942), and MacArthur (1955) are reviewed by Eysenck (1953) in some detail. He considers MacArthur's study as methodologically the most satisfying. MacArthur, following preliminary investigation, selected a large number of individual and group tests for administration, including the traditional tests which had been used in the measurement of persistence, as well as measures of intelligence, school grades, age, self-ratings, peer ratings, and ratings by teachers. Subjects were 120 boys and the influence of ability on persistence was partialed out. A Thurstone analysis of intercorrelations yielded five factors as follows: (*a*) General persistence, with peer ratings (.603) and time spent on magic square (.584) having the highest saturations; this factor ran through both ideational and physical measures, word building had a saturation of .472 and maintained handgrip .432. (*b*) A bipolar factor contrasting individuality with prestige suggestibility; tests in which subject had no knowledge about performance of classmates were positively loaded; tests where this knowledge was available were negatively loaded; this factor resembled Kremer's "will to community" factor. (*c*) A bipolar factor contrasting measures of reputation for persistence with objective measures of time spent by subject at the task; this reputation factor resembled Kremer's "stability of character" factor; further, measures opposite in sign were very similar to those defining Thornton's "keeping at a task" factor running through ideational tests. (*d*) A factor running through the physical tests and closely resembling Thornton's "withstanding discomfort to achieve a goal" and Rethlingshafer's "willingness and/or ability to endure discomfort." (*e*) A factor running through spatial and numerical tasks and interpreted as spatial-numerical persistence. MacArthur's results thus brought together in the one study many of the previous findings. A persistence score based

on a combination of the eight tests with the highest communalities correlated .30 with school marks with intelligence partialed out, and had an index of reliability of .90. MacArthur found it best to avoid suggesting that persistence was desirable and provided activities to which subject could turn when he had spent as long as he wished at the task.

Eysenck (1953) summarizes the general results of the foregoing studies as follows:

> The evidence is fairly conclusive that persistence constitutes an important trait in our culture; that this trait is of relatively unitary nature and can be measured to the extent indicated by a validity of .9. In addition to this general factor of persistence, we find groups of activities which cluster together and define more specific types of persistence, such as persistence in physical tasks or persistence in ideational tasks. These smaller and less important factors also are subject to measurement with a degree of validity probably not much below general persistence itself. Persistence as measured by tests is fairly closely related to persistence as rated by others, and can be said to predict performance in life situations to a definitely significant extent. Persistence tends to show slight correlations with intelligence, more impressive ones with "w" or lack of neuroticism and with introversion (p. 290).

These latter results, involving neuroticism and extraversion-introversion, were discovered in research conducted in Eysenck's laboratory (1947, 1952). Persistence in these investigations was measured by a physical endurance test (holding leg above an adjacent chair). Recently, Eysenck (1957) has attempted to give a theoretical account of the relationship of persistence to personality dimensions using assumptions about the development of inhibitory and excitatory potentials, a conception which is related to Pavlov's (1927) theory of experimental neurosis. Extraverts are assumed to be individuals in whom excitatory potential is generated slowly and at a weak level, but in whom inhibitory potential develops quickly to a strong level and then dissipates slowly. In contrast, introverts are assumed to be individuals in whom excitatory potential is generated quickly and at strong level, but in whom inhibitory potential develops slowly to a weak level and then dissipates quickly. Differences between introverts and extraverts in persistence are related to the differential in inhibitory potential. The stronger inhibitory potential developed in extraverts would lead to the expectation that they should show relatively less persistence at a task than introverts. This expectation is supported in the investigations using the physical endurance test.

Evaluation of Trait Studies

Without question the factor analytic approach to the study of persistence marked an advance over the earlier simple correlation-type studies. While these latter investigations did contribute a rich variety of tasks, they often appear to have involved a rather uncritical lumping together of diverse activities without much attempt to account for similarities and differences in results. The factor analytic studies contributed to the *classification* of these tasks and thus assisted in bringing some order into a complex pattern of relationships. In this respect they represented a step in the direction of scientific progress. But, while it is of value to know, for example, that ideational persistence tasks separate in factor analytic research from physical persistence tasks and that there are differences in persistence for tasks administered in a group setting and tasks administered individually, this information itself serves only as a starting point. The scientist typically goes beyond classification to explanation. He wants to know not only how phenomena may be grouped together, but also how they are uni-

formly related to other phenomena in terms of a conceptual framework which will provide both a scientific account of extant findings and a promising direction to new research. Factor analytic studies of persistence are theory oriented only insofar as they invoke the concept of trait which carries with it the implication of a stable structure transcending the immediate situation. But it is argued that such a concept offers only an incomplete understanding. The discovery of the fine-grain of the observed phenomenon will involve not only knowledge of personality structures but also a thorough understanding of the role of the immediate situation in relation to behavior, and the interaction between such situational factors and personality dispositions. It should be possible to account both for differences between individuals in persistence in the one situation, and differences in persistence for the one individual in different situations.

The next set of studies to be discussed certainly does not satisfy this interactional requirement. In fact, these investigations appear to stand at the opposite extreme from the trait studies in that they examine the effect of variations in *situation* on persistence and tend to ignore relatively stable personality variables. Thus, like the trait studies, they are one-sided. They are, however, of interest in showing how persistence, in terms of resistance to extinction, varies with changes in an acquisition series. This type of study may be conceived as bearing more upon the relationship of persistence to expectation.

Persistence Conceived as Resistance to Extinction

As indicated previously, studies with humans in which resistance to extinction is related to different types of reinforcement schedules are not commonly classified as persistence investigations. However, continuing an activity in the face of uniform nonreinforcement is similar to the familiar persistence situation in which the subject works at a task without success. The relevance of extinction studies to the present review is increased further by the fact that one common interpretation of the obtained results relates the number of responses to extinction to a concept of expectancy and its manner of change. The studies considered in the present section are restricted to those in which discussion of results involves some reference to a concept of expectancy. The reader is referred to reviews by Jenkins and Stanley (1950) and Lewis (1960) for comprehensive coverage of the partial reinforcement literature.

The general finding in these extinction studies is that:

> All other things equal, resistance to extinction after partial reinforcement is greater than after continuous reinforcement when behavior strength is measured in terms of single responses (Jenkins & Stanley, 1950, p. 222).

Jenkins and Stanley review a large number of studies which support this conclusion.

For example, Humphreys (1939b) in an early study of eyelid conditioning found that random alternation of reinforcement and nonreinforcement led not only to as much conditioning as reinforcement per trial but also to greater resistance to extinction. During extinction, responses for subjects who were partially reinforced first increased in frequency and then decreased. This result can be considered in terms of expectancy theory since the subject would presumably have a greater expectation of a reinforcement after one or two nonreinforcements, particularly since in the acquisition stage of the experiment there were never more than two successive nonreinforcements. Hum-

phreys argued that the shift from intermittent reinforcement to uniform nonreinforcement must have led more slowly to the expectation of uniform nonreinforcement for subjects who were partially reinforced, while this change in expectation would occur more rapidly for subjects who were uniformly reinforced during acquisition.

In a subsequent experiment, Humphreys (1939a) used an apparatus in which two lights were arranged on a board. The subject had to guess when one of these lights was turned on, whether or not it would be followed by the other light. Half of the subjects were trained with the first light invariably following the second; for the other half the second light was turned on only in random alternation so that it appeared half of the time. Humphreys found that, under extinction conditions (i.e., the first light was never followed by the second), the uniform reinforcement group quickly developed the hypothesis of uniform nonreinforcement. The intermittent reinforcement group showed an initial rise in expectation followed by gradual acceptance of the hypothesis that there would be no second light.

More recently, Lewis and Duncan (1958) have studied the way in which variation in the frequency of reward during an acquisition stage and variation in the length of an acquisition stage affects the number of trials to extinction and stated expectation of reinforcement. An electronic slot machine was used in the experiment and was set to pay off according to a prearranged schedule when buttons were pushed and a lever was pulled. In a factorial design, a constant payoff occurred on 33%, 67%, and 100% of trials during acquisition, combined with 3, 6, 12, and 21 acquisition plays. Following the last acquisition play extinction began with no further payoffs. The subject could play the machine for as long as he liked. Lewis and Duncan found that the larger the number of acquisition trials the less the plays to extinction. There was a tendency for smaller percentages of reinforcement to be associated with a greater number of plays to extinction, the usual partial reinforcement effect. Expectancies, measured before each trial by a rating technique, were found to increase differentially during acquisition as a direct function of the percentage of reinforcement. Expectancies decreased differentially during extinction as a direct function of the percentage of reinforcement, a result which is not inconsistent with the Humphreys interpretation. Finally, there was no clearcut statistical evidence that number of acquisition trials had any effect upon expectancies. In an earlier study (Lewis & Duncan, 1957) using the same apparatus, it was found that when magnitude of reward was varied, larger amounts of reward were associated with more plays to extinction.

Lewis and Duncan (1958) maintain that their results are consistent with a discrimination hypothesis concerning extinction (Bitterman, Federson, & Tyler, 1953). Extinction is assumed to occur because it is clear to the subject that no more rewards will occur. He responds to the acquisition series as a whole. Under conditions where extinction conditions are similar to acquisition conditions, discrimination is difficult and extinction therefore prolonged. Where acquisition and extinction series are very dissimilar, discrimination is easier and extinction therefore more rapid. Percentage of reward is an important factor in similarity-dissimilarity of the two series. If the

percentage of reward is low in the acquisition series, then the acquisition series is more similar to the extinction series; discrimination is difficult and thus extinction takes longer.

James and Rotter (1958), in an interesting methodological contribution to the literature, argue that studies of the partial reinforcement effect have failed to consider differences between those situations in which the subject is likely to see the occurrence of the reinforcements as *outside his control* and primarily contingent upon external conditions, and those situations in which the subject can relate the occurrence of the reinforcements to *his own skill.* They believe that the chance-skill dimension is an important one along which situations can be categorized. Thus, for example, Phares (1957) found significantly greater changes in expectancies for skill groups than for chance groups although all subjects had the same number and pattern of reinforcements. In research by Feather (1959b) this dimension was found to be important with respect to the influence of variation in subjective probability of success on the attractiveness of attaining a goal and the tendency to choose it. Littig (1959) in discussing the results of his study of probability preferences and subjective probability proposes a similar distinction between skill and chance situations.

James and Rotter (1958) argue that in an acquisition series involving uniform reinforcement the subject receives no cues of nonreinforcement. Hence, when the extinction series begins, he is able to utilize the first nonreinforcements as cues that the situation has changed. If he perceives control of the situation as *external,* a sudden decrease in expectancy should tend to occur and rapid extinction. But, under partial reinforcement conditions these cues of nonreinforcement are present in the training series. Hence, when the extinction series begins, the first nonreinforcement is not a new cue which can be used to discriminate a change in situation. Consequently, extinction should be more gradual, with more trials required before the subject recategorizes the situation. In a chance type of situation resistance to extinction is also increased by the subjects tendency to count and verbalize relationships. In the acquisition series he is likely to develop the hypothesis that a series of nonreinforced trials will probably be followed by a trial on which reinforcement is forthcoming. This "gambler's fallacy" may also occur during the extinction series. Thus increased resistance to extinction should result.

However, where the situation involves *skill,* the subject perceives reinforcements and cues as produced by factors controlled by himself. In the uniform reinforcement situation he is less likely (when the extinction series begins) to recategorize the situation as having changed. Under these conditions one would not expect sudden decreases in expectancy. Furthermore, when the subject is partially reinforced in the skill situation, the gambler's fallacy should not be operative since nonreinforcement is attributed to lack of skill rather than to luck factors. James and Rotter (1958) maintain that this theoretical analysis would lead to the prediction that in skill situations a 100% reinforcement group would be more resistant to extinction than a partial reinforcement group. To test this prediction they contrasted 100% and 50% random reinforcement under conditions where subjects were instructed either that success at the task was determined by chance or by their own skill. Using a simple card

guessing game presented tachistoscopically with chance versus skill instructions, they found that under skill conditions the usual superiority of the partial reinforcement group did not occur. In fact, 100% reinforcement led to less rapid extinction than 50% reinforcement, although the difference was not statistically significant. The usual partial reinforcement effect was obtained in the chance situation. The 100% chance group extinguished significantly faster than the 50% chance group.

Evaluation of Extinction Studies

The above investigations by Humphreys and by Lewis and Duncan imply that a high expectation of reinforcement developed in an acquisition series of trials will tend to be associated with low behavioral persistence as indicated in rapid extinction when rewards are no longer forthcoming. Conversely, low expectation of reinforcement will tend to be associated with high behavioral persistence as indicated in a greater resistance to extinction. However, the study by James and Rotter suggests that it would be unwise to proceed to such a generalization for all situations. Usually partial reinforcement studies have been conducted with tasks in which the reinforcements, when they occur, appear to be externally controlled and independent of the skill of the subject. In contrast, as we saw in the preceding section, research in persistence in most cases has used tasks which are on the skill side of the continuum, where success and failure can be related to the subject's own efforts and not to conditions outside of his control.

Furthermore, persistence tasks of the insoluble puzzle variety usually provide a wide and relatively inexhaustible range of alternative responses following failure, whereas in the extinction study the response tends to be restricted to a particular action. Presumably, in the former case a number of different alternative responses have to extinguish while in the latter case only one.

Finally, it is worth noting again the situational emphasis in these extinction studies. The stress is on varying the way in which reinforcements occur in an acquisition series and tends to exclude consideration of the effect of relatively stable personality differences on resistance to extinction. As indicated, these studies may be conceived as more relevant to the relationship of persistence to situationally elicited expectations. Thus, neither the trait studies nor the studies discussed in this section take account of both personality and situation parameters in interaction, and their approach is to this extent limited. The studies to be discussed in the next section do attempt to recognize this interaction in their theoretical conceptualization although they vary in the degree to which the interaction is made explicit.

Persistence Conceived as a Motivational Phenomenon

The studies in this section conceive of persistence in relation to a theory of motivation. Two theories are particularly relevant to this review: Lewinian field theory with its assumption of behavior determined by the psychological life space and all that it involves; the theory of achievement motivation (Atkinson, 1957, 1960) with its interactive assumption of motivation as a function of motives, expectations, and incentive values.

While both of these theories are interactional in the sense that each considers situational and personality parameters, it will be argued that the

latter marks an advance over the former in the way in which persistence may be conceived, in that it offers a more explicit formulation both of individual differences in motive and the way in which motives, expectations, and incentives are combined. Therefore it is considered that the theory of achievement motivation offers greater potential for an explicit account of persistence in achievement contexts than Lewinian field theory. In this section, as in the discussion of trait studies, successive sets of studies exemplify an advance in the evolution of scientific explanation, in this case from fairly general field theory to a more explicit model concerned with behavior in the achievement situation.

Lewinian Field Theory

Lewinian field theory in its basic equation $B = f(P,E)$ has long recognized the necessity of considering behavior in terms of interacting personality and situational factors. It is of interest to examine the approach taken to the problem of persistence by this theory.

The typical situation employed in the investigation of persistence can probably be represented topologically and dynamically in Lewinian terms as a frustration situation in which a person in a state of tension is separated at some psychological distance from a goal (or region of positive valence) by a barrier. This barrier is the source of restraining forces which oppose the driving forces acting upon the person in the direction of the goal. The barrier may be objectively insurmountable, as when the subject is given an insoluble puzzle and asked to solve it, or the barrier may represent a very difficult task in which case the opposing restraining forces would be very strong but could possibly be surmounted. There may be other regions of positive valence in the psychological environment to which the subject may turn if he so desires.

It is true that there are some situations in the persistence literature which do not appear to conform to this paradigm. For example, the investigation of persistence against boredom and fatigue would appear to be more related to the Lewinian studies of satiation, and dynamically different from the frustration type of situation mentioned above. But Lewin (1946) himself appears to consider persistence in terms of the person-barrier-goal situation when he writes: "What is usually called persistence is an expression of how quickly goals change when the individual encounters obstacles" (p. 824). He discusses research by Fajans (cited in Lewin, 1946) as falling within this context. Fajans, in a study of success, persistence, and activity in infants and young children, investigated the effect of separating children from a goal object at different distances. She found that previous failure at a task decreased persistence when subjects were again confronted with the same type of difficulty and when persistence was measured by duration of approach. In contrast, success led to a relative increase in persistence. When the same task was repeated, a combination of success and praise was more effective in increasing persistence than success alone. Similar effects of success and failure were found by Wolf (1938). Persistence was also found to increase with decreasing distance from the goal. These results are relevant to the present review to the extent that previous success and failure may be considered important determinants of present expectations of success and failure. Considered in this light, the Fajans research implies

that persistence is positively related to the subject's expectation of success and negatively related to his expectation of failure.

It is important to note that Fajan's research, and indeed the great bulk of Lewinian investigations, does not take account of individual differences in both nature and strength of motive. While the concept of tension is basic in Lewin's conceptualization of the person and influences the way in which the person sees the environment, it is not spelled out in any detail in the theory. It is a concept consistent with the field emphasis of a person in an environment each influencing the other, but it applies to an individual and differences between persons with respect to tension are not explicitly formulated. One might ask how many different types of tension there are, whether Individual X is stronger than Individual Y with respect to one type of tension, how these tensions develop, to what extent they are stable, what is their precise relationship to valence, etc. But perusal of Lewinian field theory does not provide definite answers to these questions. Perhaps this is a consequence of the emphasis on the individual case, and the protest against Aristotelian class concepts. In actual experiments it appears to lead to operations which are more concerned with manipulating the psychological environment of a person, and details of differences in personality structure tend to be left unspecified. Where the P is manipulated the operations are directed to producing an *intraindividual* effect for the one person rather than studying the effect of variation *between* persons.

That personality differences are important is recognized by Henle (1955) in her research on substitute value within a Lewinian context. Thus she writes:

> the relevant segment of behavior does not consist simply of activity directed to satisfy a quasi-need to complete a particular task, but must be thought of as activity to a more inclusive goal (p. 536).

Presumably then we need to consider not only transient situational factors but also the specific behavior of the person in relation to more general and inclusive life goals and motives. In this sense the theory of achievement motivation (Atkinson, 1957, 1960) is more explicit than Lewinian field theory. It involves not only a conceptualization of the effects of momentary situation (in terms of the concepts of expectation and incentive value) but also provides for the influence of relatively stable dispositions (or motives) on behavior. The theory is more restricted than Lewinian field theory since it is specifically directed to the analysis of behavior in achievement contexts where performance may be related to standards of excellence. However, it is possible that the general "expectancy value" approach, of which the theory of achievement motivation is a particular example, may ultimately clarify our understanding of behavior in many other types of situation.

Theory of Achievement Motivation

Of the four studies of persistence to be considered in this section only the latter two studies by Atkinson and Litwin (1960) and by Feather (1960) are historically an outcome of the theory of achievement motivation. The other two investigations by Winterbottom (1958) and by French and Thomas (1958) preceded the theory and are more readily classified with earlier studies (McClelland, Atkinson, Clark, & Lowell, 1953) which were concerned initially with the development of a valid measure of the achievement motive. This validation was of two main kinds: experiments concerned with the ef-

fect of experimental arousal of motivation on imaginative thought, and experiments concerned with the effect of individual differences in motive strength on behavior. The initial approach adopted towards validating the measuring instrument had a common sense basis. It was expected that the achievement motive would be more strongly elicited under achievement oriented or test conditions than in a relaxed situation, and that subjects with high achievement motive would demonstrate this in behavior, e.g., by working harder at a task than subjects with weaker achievement motive. The studies by Winterbottom, and by French and Thomas, fit into this class since they investigated the common sense prediction that subjects with high achievement motive should have relatively higher motivation to succeed and hence should tend to show greater persistence.

Winterbottom (1958) as part of an investigation of the relationship of n Achievement to early childhood training experiences, observed 29 8-year-old boys in a puzzle solving situation. During the test each child was given the opportunity to ask for help whenever he wanted it, and was offered help and rest at intervals. Using the projective thematic apperception (TAT) method (McClelland et al., 1953) of measuring the achievement motive, Winterbottom found that boys who were high in n Achievement on stories obtained immediately after the puzzle solution period (i.e., under achievement oriented conditions),less frequently requested help and more often refused an invitation to stop work and rest than boys low in n Achievement. Boys high in n Achievement under both relaxed and achievement oriented conditions more often refused help even when it was offered. Thus, she obtained evidence for greater persistence in the high n Achievement group in the sense of desire to continue with the task without external assistance or rest. In common with a great deal of research in achievement motivation, Winterbottom defined high and low n Achievement groups on the basis of a median split in the distribution of scores.

French and Thomas (1958) in a study involving 92 subjects from a United States Air Force base, found a clear positive relationship between time spent on a complicated mechanical problem and n Achievement assessed by the French Test of Insight, an apperceptive content device scored for n Achievement in the same way as the TAT (French, 1958). Again, high and low n Achievement groups were contrasted on the basis of a median split. The majority of the high motive group used most or all of the time available for the puzzle (35 minutes), while only a few of the low motive group continued with the puzzle to the end. Thomas (1956) had previously found that strength of achievement motive was related to the length of time a subject would work at a problem without objective knowledge of progress.

As we have indicated, these two studies were not conceived with any theoretical model in mind. However, it was natural that, with the accumulation of research concerning achievement motivation, attempts would be made to conceptualize results in terms of some systematic framework. McClelland and Clark (McClelland et al., 1953, Ch. 2), in the course of a discussion of a more inclusive theory of motivation involving the concept of affective arousal, had made some suggestions about the status of the achievement motive with respect to this theory. In the *Nebraska Symposium on Motivation* Atkinson (1954), drawing on formalizations of expectancy theory by MacCorquodale and

Meehl (1953) and Tolman and Postman (1954), analyzed the role of the situation in relation to behavior in achievement contexts in terms of the expectations which are elicited. This line of thinking was further elaborated in his later analysis of risk taking behavior in terms of a theory of achievement motivation (Atkinson, 1957). The general approach of which the theory of achievement motivation is a particular case, considers motivation[2] expressed in the direction, magnitude, and persistence of behavior, as a positive function of the strength of motive within the person, the strength of the expectancy of satisfying the motive through some action instrumental to the attainment of a goal or incentive, and the value of the specific goal or incentive that is presented in a given situation. As such, this approach belongs to a class of expectancy value theories which all involve somewhat similar concepts (Feather, 1959a).

The theory of achievement motivation is specifically addressed to those situations in which performance at a task may be evaluated against a scale of excellence related to difficulty. In such a situation, successful performance at a difficult level is highly valued and is generally accompanied by a feeling of pride in accomplishment, while failure at an easy level is negatively valued and is generally accompanied by a feeling of shame and embarrassment. The theory involves the following six variables: the subjective probability or expectancy of success (P_s), the subjective probability or expectancy of failure (P_f), the positive incentive value of success (I_s), the negative incentive value of failure (I_f), the motive to achieve success (M_s), and the motive to avoid failure (M_{af}). The subjective probabilities refer to situationally aroused expectancies in the person concerning the probability of the consequences of instrumental acts. Positive incentives refer to potential rewards and goals, negative incentives to potential punishments and threats. Motives are conceived as dispositions within the person to approach certain classes of positive incentives and to avoid certain classes of negative incentives. The motive to achieve success (M_s) is conceived as a disposition to derive satisfaction from successful exercise of skill; the motive to avoid failure (M_{af}) is conceived as an independent disposition to experience shame and embarrassment as a result of failure. Both of these dispositions are assumed to be activated when the situation arouses expectancies in the person that his performance will be evaluated against standards of excellence associated with success and failure. These motives are considered to be relatively stable dispositions of the person acquired early in life.

Specific assumptions are made in the theory concerning the incentive values of success and failure. These assumptions were suggested in more general form in the resultant valence theory of level of aspiration (Lewin, Dembo, Festinger, & Sears, 1944). There it was assumed that the attractiveness of success increases with decrease in the expectation of success, and that the repulsiveness of failure increases with decrease in the expectation of failure. In addition Lewin et al. assumed that the subjective probability of failure is one minus the subjective probability of success. The relationship of attractiveness of success and repulsiveness

[2] The theory draws a sharp distinction between motive and motivation. Strength of motive is one influence on strength of motivation. Other factors influencing strength of motivation are levels of expectation and magnitude of incentive value.

of failure to subjective probability is made more explicit in the theory of achievement motivation. It is assumed that the positive incentive value of success is one minus the subjective probability of success: i.e., $I_s = 1 - P_s$. Further, the negative incentive value of failure is taken as the minus value of the subjective probability of success: i.e., $I_f = -P_s$.

The theory assumes that the basic variables combine multiplicatively to determine positive achievement motivation ($M_s \times P_s \times I_s$) and negative failure avoidant motivation ($M_{af} \times P_f \times I_f$). These two component motivations combine additively to generate resultant motivation.

The theory implies that this resultant motivation to perform the task is positive when the motive to achieve success is stronger than the motive to avoid failure (i.e., $M_s > M_{af}$) and negative or task avoidant when $M_{af} > M_s$. Hence, an individual in whom $M_s > M_{af}$ should demonstrate positive interest in achievement related tasks whereas an individual in whom $M_{af} > M_s$ should tend to avoid achievement related tasks unless he is constrained to perform them. Predictions can be made from the theory concerning the effects of individual differences in the strength of M_s and M_{af} on level of task performance, risk taking, and persistence. These predictions have been tested in a number of investigations summarized in a recent review (Atkinson, 1960).

Of particular interest to the present review is the study carried out by Atkinson and Litwin (1960). Using the theory of achievement motivation they predicted that, holding task constant, stronger M_s should be associated with greater persistence, and stronger M_{af} should be associated with less tendency to persist. Actually the study had a much wider set of aims for it was designed to show the extent to which the resultant motivation as predicted from the theoretical model would be manifested in the defining characteristics of behavior qua motivated, namely, choice (direction), performance level, and persistence. In particular, Atkinson and Litwin were interested in providing evidence for the construct validity of the French Test of Insight (French 1958) and the Mandler-Sarason Test Anxiety Questionnaire (Mandler & Sarason, 1952) as methods for assessing strength of M_s and M_{af}, respectively. The construct validity of these tests would be strengthened by showing that, when they are used for assessing the corresponding motives, measures of risk taking, performance level, and persistence (holding task constant in a crude qualitative way) are all consistent with implications from the theory of achievement motivation.

Using 49 undergraduate students enrolled in a sophomore-junior level psychology course at the University of Michigan, Atkinson and Litwin observed their behavior in a simple ring toss game as indicative of risk taking, the grades they received on their final exam in the course as indicative of performance level, and the amount of time they spent working at the final exam as a measure of persistence. Taking scores for the Test of Insight and the Test Anxiety Questionnaire separately and classifying subjects as high or low for the corresponding motive on the basis of a median split in the respective distribution, they found as predicted that n Achievement (M_s) was positively related and test anxiety (M_{af}) was negatively related to preference for intermediate risk, performance level, and persistence. The prediction was clearly improved when subjects were classified *simultaneously* on the basis of the two tests using me-

dian splits. For example, subjects classified high in n Achievement and low in test anxiety worked longer at the final exam than subjects who were classified low in n Achievement and high in test anxiety. Subjects classified high for both motive measures and low for both motive measures had persistence times falling between those of the two extreme groups.

Thus, the study provided clear support for the construct validity of the Test of Insight and the Test Anxiety Questionnaire as methods of assessing M_s and M_{af}, respectively. Predictions from the theory of achievement motivation were confirmed using each test separately and the two tests in combination. The three dependent variables of the investigation were positively correlated implying that individual differences in strength of motive tend to be stable from situation to situation.

It should be noted that the Atkinson-Litwin study was restricted to the investigation of persistence at a task in relation to differences in strength of achievement related motives. It made no attempt to vary systematically expectations of success and failure as related to situational cues or to specify clearly the level of initial P_s. Nor did it attempt to account for why an individual stops working at a task. A recent study by Feather (1960, 1961) focuses on these problems for the first time and investigates persistence in relation to the *interaction* of motives and situationally elicited expectations by varying both factors simultaneously. This study therefore helps to clarify the more specialized questions raised at the beginning of this review concerning the relation of persistence at a task both to initial expectation of success and to individual differences in strength of motive to achieve success and motive to avoid failure. Hence the approach will be considered in some detail.

The theoretical analysis involved in the investigation is applied to the persistence situation where the subject works at an achievement task which is presented to him as part of an important test and which is in fact insoluble. He undergoes repeated failure in his attempts to perform the task but may turn to an alternative achievement task when he so desires. The analysis is based on the relationship of total motivation to perform the task to total motivation to perform the alternative. It is assumed that the subject will persist at the initial task as long as total motivation to perform it is stronger than total motivation to perform the alternative.

Total motivation to perform the initial achievement task is attributed to the following three components: motivation to achieve success at the task, motivation to avoid failure at the task, and extrinsic motivation to perform the task. Total motivation to perform the alternative activity is attributed to the same three component motivations since the alternative is also achievement related. Both motivation to achieve success and motivation to avoid failure are conceptualized in accordance with the theory of achievement motivation as multiplicative products of strength of motive, level of expectation, and magnitude of incentive value. Extrinsic motivation refers to motivation to perform the task attributable to motives other than those which are achievement related (i.e., motives other than M_s and M_{af}). For example, the usual social constraints (e.g., desire for approval, fear of disapproval) provide an important source of motivation in any

situation where a subject is required to work at a task.[3] Ultimately such extrinsic motivation may also be conceptualized as resulting from relatively stable personality dispositions (motives) in interaction with more transitory situational influences (expectations and incentive values). Extrinsic motivation to comply with instructions may, for example, vary with the strength of affiliation motive and the degree to which the subject expects that compliance will produce certain affiliation rewards in the situation, e.g., approval for being a cooperative subject. In the present analysis of persistence, extrinsic motivation to perform the initial achievement task is assumed to be stronger than extrinsic motivation to perform the alternative since the initial task is presented by the experimenter as the first in a defined sequence of achievement tasks. Furthermore, both sets of extrinsic motivation are assumed to be constant across the different experimental conditions.

It is assumed in the theoretical analysis that the subject will turn to the alternative achievement activity whenever total motivation to perform the initial task becomes weaker than total motivation to perform the alternative. The problem then becomes that of specifying the basis for a *decrease* in total motivation to perform the initial task as the subject works at it unsuccessfully. This decrease is assumed to be mediated by changes in both the motivation to achieve success at the initial task and the motivation to avoid failure at the task. These changes are in turn assumed to be determined by a successive decrease in subjective probability of success (P_s) as the subject repeatedly fails at the initial achievement task. Hence *decrease in expectation of success with repeated failure becomes the basic dynamic principle.* When this principle is used in conjunction with the theory of achievement motivation and certain additional assumptions[4] it becomes possible to derive the following four hypotheses:

Hypothesis 1 states that subjects in whom the motive to achieve success is stronger than the motive to avoid failure ($M_s > M_{sf}$) should persist longer at a task for which the initial subjective probability of success is high ($P_s > .50$) than similar subjects for whom the initial P_s is low ($P_s < .50$).

Hypothesis 2 states that subjects in whom $M_{sf} > M_s$ should persist longer at a task for which the initial P_s is low ($P_s < .50$) than similar subjects for whom the initial P_s is high ($P_s > .50$).

Hypothesis 3 states that when initial P_s is high ($P_s > .50$), subjects in whom $M_s > M_{sf}$ should persist longer at a task than subjects in whom $M_{sf} > M_s$.

Hypothesis 4 states that when initial P_s is low ($P_s > .50$), subjects in whom $M_{sf} > M_s$ should persist longer at a task than subjects in whom $M_s > M_{sf}$.

Thematic apperceptive stories obtained under neutral conditions and Mandler-Sarason Test Anxiety Questionnaire were used to provide meas-

[3] This is especially so for subjects in whom $M_{sf} > M_s$. If these subjects are to perform an achievement task at all, some stronger positive motivation must exist to oppose their tendency to avoid the task.

[4] It is assumed that P_s for the alternative task is constant across the experimental conditions, that reduction in P_s for the initial task to a particular value will require more unsuccessful attempts at the task when P_s is initially high than when it is initially low, and that rate of decrease in P_s is not systematically related to strength of M_s or M_{sf}.

ures of n Achievement (M_s) and test anxiety (M_{sf}) for 89 male college students from an introductory course in psychology at the University of Michigan. It was assumed that $M_s > M_{sf}$ for subjects classified high n Achievement–low test anxiety (in terms of median scores); in subjects classified low n Achievement–high test anxiety it was assumed that $M_{sf} > M_s$. Later, four complex perceptual reasoning tasks were administered to 34 of these preselected subjects in individual test sessions. The first and third tasks were insoluble; every trial taken by the subject at each of these tasks resulted in failure. The second and fourth tasks were soluble. Initial P_s for each of the four tasks was induced by reporting fictitious norms which indicated percentage of students likely to succeed at the task. For half the subjects the successive norms were 70%, 50%, 5%, 50%; for the other half the norms were 5%, 50%, 70%, 50%. Measures of persistence were obtained on the first and third insoluble tasks. Persistence was measured by total trials or total time the subject worked at each insoluble task before turning to the next task in the set.

Results for the first task clearly supported the four hypotheses. For example, subjects classified as high n Achievement-low test anxiety persisted longer at the first insoluble task when it was presented as easy (70% norm) than when it was presented as very difficult (5% norm). This result implies that subjects in whom $M_s > M_{sf}$ show greater persistence when initial P_s is high than when initial P_s is low which is in accordance with the first hypothesis. In contrast, subjects classified as low n Achievement-high test anxiety persisted longer at the first insoluble task when it was presented as very difficult (5% norm) than when it was presented as easy (70% norm). This result is consistent with the second hypothesis. In the same way, results from the first insoluble task are consistent with Hypotheses 3 and 4.

None of the expected differences in persistence between the different experimental conditions occurred on the third task but there was a tendency for changes in persistence from the first to the third task, using each subject as his own control, to be consistent with hypotheses. However, the necessity for unanticipated interruption of a sizeable number of extremely persistent subjects on the first and third tasks, and the possibility of uncontrolled sequence effects, make interpretation of results for the third task equivocal. Post-experiment questionnaire information concerning assumptions involved in procedures and hypotheses tended to support the theoretical explanation.

Evaluation of Motivational Approach

The type of approach adopted in the above investigation raises a number of issues that are relevant for the future study of persistence:

1. The theoretical analysis suggests the importance of specifying the components of both total motivation to perform the task with which the subject is presented and total motivation to perform the alternative to which he may turn, when attempting to predict degree of persistence. The persistence situation is similar to a complex problem in decision where the subject is continually confronted with the choice of continuing with the unsolved task or turning to the alternative. From this point of view the basic theoretical problem is that of specifying precisely all of the component motivations involved in the decision, the way in which they combine to determine a resultant, and the manner in

which they change as the subject works unsuccessfully at the task.

2. The theoretical analysis also suggests the possibility of conceptualizing each of the component motivations as a function of strength of motive, level of expectation, and magnitude of incentive value. Such a conceptualization would necessitate the precise specification and measurement of the particular motive, expectation, and incentive value assumed to determine any component motivation, together with assumptions about how these three factors combine to determine the strength of the component motivation. It is of interest to note that most expectancy value theories have employed a multiplicative rule of combination (Feather, 1959a).

3. The theoretical analysis focuses attention on change in expectation as the basic dynamic principle mediating change in motivation. The task used in the investigation was one in which expectation of success could be assumed to decrease with experience since the subject failed at every attempt. But there are tasks, involving some degree of partial success, where expectation of success might be expected to rise initially before falling. Furthermore, it appears important to consider the degree to which the task involves skill. It is a basic assumption in the investigation that it should take more unsuccessful attempts at a task to reduce an expectancy to a particular level from a high initial expectation of success than from a low initial expectation of success. The results from the investigation and from the earlier study by James and Rotter (1958) suggest that this assumption is tenable in situations where the subject can relate success to his own efforts or skill, and failure to his own inadequacy rather than to the influence of external agencies beyond his control. However, when the subject considers success and failure beyond his control (as in chance-type situations), expectancy may decrease more rapidly in extinction when initial expectation of success is high than when it is low, an assumption which is consistent with the usual partial reinforcement effect obtained under external control conditions. Clearly then, predictions about persistence using the dynamic principle of expectation change require explicit assumptions about the *manner* in which expectation changes with experience at the activity and assumptions about conditions affecting the *rate* of change in expectation.

4. Finally, the theoretical analysis suggests by contrast a number of persistence situations which differ in important respects from the one investigated. In particular the following persistence situations appear worthy of study:

a. Situations where performance of the alternative activity involves motives which are not involved in performance of the initial task. In the present investigation both initial task and alternative task belong to the same class of activity. Both tasks are achievement related and total motivation to perform each is attributable to the same component motivations. But one can conceive of situations where performance of the alternative involves different component motivations. For example, in the study of persistence by Atkinson and Litwin (1960), the activity in which the subject engaged when he left the examination room may have been quite unrelated to achievement, involving a different set of component motivations.

b. Situations where component motivations involve the influence of incentive values which are indepen-

dent of expectations. In the specific achievement context dependencies are assumed between incentive values and expectations, e.g., $I_s = 1 = P_s$. But in most other situations it would be assumed that incentive values and expectations are independent. This means that, in the more general case, motivation to perform the activity would be expected to decrease continuously with decrease in the expectation of goal attainment. This decrease is in contrast to changes assumed to occur in the achievement situation where both motivation to achieve success and motivation to avoid failure show an initial increase in strength as the expectation of success falls to $P_s = .50$.

c. Situations where the incentive is objectively present, e.g., a young child trying to overcome a barrier in order to get some candy. In the present investigation and also in extinction studies the incentive is not in view and the experimenter has to take special precautions to ensure that the subject does not develop the expectation that there is in fact no incentive, e.g., that there is no solution to the problem or that the apparatus has been "fixed" to prevent the occurrence of further reinforcements. Should this happen the situation would become one in which the subject sees success and failure as beyond his control.

d. Situations involving different assumptions about extrinsic motivation. In the present study it was assumed that extrinsic motivation to perform the initial achievement task is stronger than extrinsic motivation to perform the alternative. This assumption is a reasonable one when tasks are presented in a defined sequence with the implication that one has to be performed before the other. However, one can conceive of situations where different assumptions about extrinsic motivation could be made. For example, extrinsic motivation may be assumed constant across tasks in the type of situation where the subject has free choice among various alternatives. The typical level of aspiration situation falls into this class. Thus, in a ring toss game the subject can select any one of a number of different lines from which to throw the ring. The only constraint is that he make a choice. There is no suggestion that he should follow a definite sequence in selecting some lines before others. There may also be situations in which extrinsic motivation to perform the alternative activity is stronger than extrinsic motivation to perform the initial task. For example, the experimenter might present the first task as a practice item and attach little importance to it. In contrast, the alternative might be introduced as the test item and the experimenter might suggest that this is the task in which he is really interested. Thus, the theoretical approach suggests a wide array of different classes of persistence situation. It is believed that the kind of interactional approach discussed above, based on a motivational analysis, will help to elucidate the investigation of persistence in these other types of situation.

Summary and Conclusions

The present review has attempted to distinguish between different approaches made in the literature to the study of persistence. As a more specialized aim, it has examined the relationship of persistence at an achievement task to the subject's initial expectation of success and to the strength of his achievement related motives. The survey of the literature suggests the following main conclusions:

1. Studies of persistence may be

classified into three main classes in terms of the extent to which the approach adopted is personality oriented, situation oriented, or considers both personality and situation parameters.

2. Trait studies of persistence are personality oriented and concentrate on stable characteristics of the person which are assumed to transcend the immediate situation and to determine some consistency in behavior. This type of approach has difficulty in accounting for variations in persistence from situation to situation.

3. Studies of persistence conceived as resistance to extinction are situation oriented and concentrate on properties of the immediate situation, particularly the characteristics of the acquisition series. This type of approach has difficulty in accounting for variations in persistence from person to person. Extinction studies of the partial reinforcement type offer suggestive evidence concerning the relationship of persistence to expectation but there are problems in generalizing these results which are related to important differences between the typical partial reinforcement and persistence situations.

4. Studies which conceive of persistence as a motivational phenomenon in general take both person and situation parameters into account. This type of approach is thus unlike the two preceding ones for it has the potential of being able to account both for variations in persistence from situation to situation and for variations from person to person. In addition, it allows for the study of both in interaction. Lewinian field theory, while recognizing the interaction of person and psychological environment in its basic equation, appears to deal mainly with variations in the latter in its actual experimentation. The theory of achievement motivation, developed by Atkinson, is more explicit in recognizing the interaction of stable aspects of the personality (motives) and more transitory situationally determined influences (expectations and incentive values) in determining motivation.

5. A recent experimental study of persistence in an achievement context (Feather, 1960, 1961) is based on a detailed analysis of the different motivational components involved in performance of the initial achievement task and performance of the alternative achievement task. A dynamic principle of decrease in expectation of success as the subject works at the initial task unsuccessfully is used in conjunction with the theory of achievement motivation to generate differential predictions about persistence for subjects differing in the relative strength of achievement related motives and in initial expectation of success. Results are in agreement with predictions. For example, subjects in whom it is assumed that the motive to achieve success is stronger than the motive to avoid failure persist longer at the initial achievement task when it is presented to them as easy rather than as very difficult; in contrast, subjects in whom it is assumed that the motive to avoid failure is stronger than the motive to achieve success do just the reverse and persist longer when the achievement task is presented as very difficult rather than as easy.

6. The study indicates the possibility of considering persistence as a motivational phenomenon, where the theory of motivation considers the interaction of both personality characteristics and situationally determined influences. The theoretical analysis involved in the investigation shows: the importance of a detailed analysis of the component motiva-

tions involved in performance of both initial task and alternative, the possibility of conceptualizing each component motivation in "expectancy value" terms, and the importance of change in expectation as a dynamic principle mediating change in motivation. The theoretical analysis also suggests a number of different types of persistence situation worthy of further investigation.

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COGNITIVE LEARNING IN INFANCY AND EARLY CHILDHOOD[1]

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How early can a child learn complex cognitive operations? Can a preschool child make substantial progress with verbal symbols and other abstract concepts? If so, how soon and under what conditions? Strangely enough, these important questions scarcely have been asked in the psychological literature during the present century. Why?

In this review we shall try to answer these and other related questions through a critical examination of representative studies on cognitive learning in early childhood. Our object is to show how the neglect of certain key problems has contributed to psychology's low estimate of the young child's potential for cognitive learning.

Learning in the preschool years has generally been known by almost any other name than cognitive learning. Yet, there is increasing awareness that cognition is involved in all mental processes, from conditioning, discrimination, and perception to intellective processes, concept formation and, of course, cognitive functioning itself (cf. Mussen, 1960). Unfortunately, these processes often have been treated as if they were isolated unitary categories of functioning (cf. Gibson, 1953; Gibson & Gibson, 1955; Jones, 1954; Munn, 1954; Vinacke, 1951; Wohlwill, 1960).

It is more logical, in many ways, to define even the simplest act of perception as a process incorporating rudiments of ideation. The abstracting of attributes is almost necessarily integral to perception, while higher intellectual activities evolve from a process of combining the simpler perceptual acts.

Accordingly, the review will begin with a brief comment on the early acquisition of simple abilities. After devoting some space to motor development (gross and fine), we shall then survey the literature on the early learning of complex cognitive abilities. Studies will be organized into the following categories: verbal memory, language, conceptual processes, and intelligence (IQ), and special cognitive processes—reading, mathematical, musical, drawing, and writing abilities. There will also be a special section covering the relationship of early intellectual stimulation to emotional development. Methodological criticisms will appear throughout the review and will be summarized in a concluding discussion.

Simple Abilities

The majoritity of studies of perceptual-cognitive functioning in the preschool child do not attempt to ascertain more than the status of abilities at a given age level. The focus has been on simple discrimination or perceptual problems embracing no more than one or two elementary concepts. Moreover, responses seldom have been followed over more than a short time span.

There already are available surveys of simple abilities of this kind (e.g., Gibson, 1953; Munn, 1954;

[1] The writer is much indebted to Helen L. Koch for her critical reading of an earlier version of the manuscript.

Wohlwill, 1960). We need only add here that many perceptual abilities, such as those involving discrimination of light, sound, color, form, depth, and size constancy are reported to be well established by 3–4 years of age, often before. Evidence of higher (second) order conditioning (Marinesco & Kreindler, 1933) and stimulus generalization (Jones, 1931) have been observed as early as 15 months. Transfer of discriminations to other sets of stimuli differing on the same cues of size and shape has been found as young as 18 months (Rüssel, 1931).

This pattern of findings suggests that concept formation begins during infancy. The conclusion is supported further by studies on problem solving, which are particularly relevant here. Several investigations show that children well under 3 can learn concepts based on the use of tools for solving a problem (Alpert, 1928; Matheson, 1931; Richardson, 1932, 1934; Sobel, 1939). In Richardson's experiments, infants of 20–52 weeks learned to solve problems of increasing levels of difficulty. The problems required the child to get a lure (toy) by pulling a string or to ring a bell by turning a lever.

The ability of 2-year-olds to solve a problem based on a principle has been demonstrated by Roberts (1932), who used 43 subjects, 2–5 years of age. The principle involved selecting the only door (of three) which matched in color a corresponding toy airplane suspended over it. All of Roberts' children solved this problem, although only those over 2 years were able to verbalize the principle or generalize it to a new problem.

It is important to note that the foregoing achievements can not automatically be interpreted as ability ceilings for the ages cited. To determine these ceilings, even for simple abilities, we must probe a child's progress in prolonged practice, regardless of age.

Only Ling and Welch have done any work along these lines. Ling (1941) found that several months of training improved the ability of infants between 6 and 15 months of age to discriminate simple, geometrical shapes (circle, square, triangle, etc.). Infants could discriminate forms almost irrespective of changes in size or position.

Welch's work is especially valuable, not only because of his long-term training experiments, but also because he defined discrimination learning in relation to concept formation. Welch (1939a, 1939b) initially obtained gross discriminations involving concepts of size at 12 months and form an area by 14 months. With prolonged training between the ages of 18–28 months, another group of infants greatly refined their discriminations of form and area. They succeeded in making discriminations as fine as 1 or even .5 inch. The mean of the experimental group, at 27 months, reached a level not attained by the controls until 53–60 months of age. Considering the extremely young age of Ling's subjects, and that Welch's subjects often were low IQ institutional children, these results promise much for studies of learning at more complex cognitive levels.

Motor Development

Both perception and cognition undoubtedly feature in motor functioning: the more complex the skills, the greater their role. Their involvement probably is greater during the initial stages of learning, where it is necessary to identify and coordinate dimensions of a motor task. Since the

role of cognition in motor functioning seldom has been discussed, selected studies from this area will be covered in this review. The complexity of learning in relation to the duration of training will be the primary focus.

There have been two main types of studies of motor processes in children, other than those of the short-term learning variety. Both of these have been typically cast in the framework of maturational hypotheses. In one approach, producing the greater bulk of studies, work seldom has gone beyond defining and measuring a range of more or less simple motor skills, both gross (e.g., crawling or climbing) and fine (e.g., apprehending or releasing a pellet). Little attention has been paid to the influence of experience on the development of these skills. It usually has been assumed that skills are acquired through "normal" processes of maturation, following a definite sequence of "stages" of motor development. Gesell and his followers at Yale (e.g., Gesell, Halverson, Thompson, Ilg, Castner, Ames, & Amatruda, 1940; Gesell & Ilg, 1949), Bayley (e.g., 1935), Shirley (e.g., 1931), and others have accumulated much data of this nature.

The second type of motor investigation has been designed to determine the relative importance of maturation and learning in early development (cf. Gesell & Thompson, 1929; Hicks, 1930a, 1930b; Hicks & Ralph, 1931; Hilgard, 1932, 1933; McGraw, 1935, 1939; and others). The introduction of moderately long training periods, the teaching of relatively complex skills, and the use of control subjects are all found in this class of studies. In these studies an experimental group (or identical twin) usually has been trained for several weeks or more. Controls have then been given similar training, but often for shorter periods. Experimental and control children have been alternately kept in a normal or deprived environment while the matched groups have undergone periods of training. In some cases (e.g., Hicks, 1930a, 1930b) the control group was given no special training.

Nearly all investigators have found some evidence that, while training in specific skills often improves performance, the amount of learning has been greater when the training has been deferred until the children were at least a few weeks older. They have frequently concluded, therefore, that age (maturation) is a more vital agent than experience in development. Many believe that training in skills of this type is more efficient as neural structures mature—up to a certain "optimum" age, which varies with complexity of skill.

Often underplayed, however, is the fact that specific training has invariably produced large gains, regardless of whether training came early or late in development. In addition, partly as a result of the maturational bias, there have frequently been methodological shortcomings. These have further lessened awareness of the influence of experience upon development. In the first place, most studies have dealt with simpler skills for which there is evidence of ability "ceilings" or physiological limits. For example, in Hilgard's (1932) experiment on teaching 10 2–3 year old children buttoning, climbing, and cutting with scissors, the experimental children's learning curve tended to fall off toward the end of their 12-week training program. Such a ceiling limits the relative advantage possible from longer training. Similarly, Shirley (1931) met limited success in trying to accelerate the speed of development in walking of her 25 in-

fants. Again, are we not dealing with a skill tied closer to biology, as McGraw (1935) suggests, than is true for more complex skills and categories of knowledge?

Interesting evidence on the importance training may have in developing complex skills is reported by Mattson (1933). She found, that in subjects ranging from 58 to 72 months in age, training in a rather simple rolling-ball maze yielded little if any advantage to the trained group. With more complicated patterns, however, and as the patterns grew in complexity, the superiority of the trained group increased over that of the untrained.

Another frequent error in experimental design has probably produced an advantage for the control children. Prior to their own training, and while the experimental children were undergoing training, the controls typically received a certain amount of experience in related motor activities as well as in cognition generally. Both of these types of experiences would be expected to facilitate the subsequent learning of the controls. Yet most investigators in their conclusions, while mentioning these related experiences, have been inclined to count gains accruing from this period as the work of maturation alone. It appears, then, that maturation and general experience have been confounded. Moreover, given the stress in the American culture upon the value of sensory-motor experience, this influence upon the development of the controls should not be minimized.

Among other experimental defects of these earlier experiments, has been the omission of such variables as personality and emotional dynamics. In contemporary thinking, they are widely considered to be highly potent influences on the learning process. For example, Gesell's Twin C was apparently, from the age of about 1 year more socially responsive, vocally articulate, and emotionally dominant over her experimental twinmate (Gesell & Thompson, 1929, 1941; Strayer, 1930). These are traits which readily could have enhanced her facility for learning.

Worth noting is the fact that the same person characteristically assumed the role of teacher for both the experimental and control groups in these experiments. In addition to the bias which his knowledge of and investment in the experiment gave him, his teaching skills for the particular training schedules presumably improved for the repeat performance with control children. All of these circumstances probably favored a maturational hypothesis.

In several experiments (Hicks, 1930a, 1930b; Hicks & Ralph, 1931; Hilgard, 1932), the subjects' ages spanned periods of from 1 to 4 years—periods which loom large in comparison with the few weeks of training allotted the experimental group. Indeed, age differences among subjects in some instances represented more than the total life experience of the younger subjects (2-year-olds). Yet, experimenters apparently assumed that maturational factors in motor development worked with similar effectiveness on children 2–6 years of age. Analysis of age trend variations might have proved rewarding.

There have been virtually no motor investigations focused on exploring training methods suitable for the early years. In Shirley's study, for example, we do not know whether her didactic methods—coaching and verbal persuasion—were either appropriate or sufficient for stimulating gross motor development. Especially in view of the low order of verbal

abilities prevailing at this age, different conditions and techniques may be more essential. Among these are a permissive, tension-free and play oriented atmosphere, together with the presence of effective imitation models, i.e., skilled peers.

Studies of motor development, even where training has been offered, also have failed to measure the effects of pre-experimental experience upon abilities. Basic generalizations and attitudes relative to motor functioning are undoubtedly acquired from the first months after birth. Serving as indispensable foundations for later learning, such schemas (to use Piaget's concept) are probably less easily acquired or altered at later stages. Nor have many experiments taken into account a related problem of equal significance: the span of training must be long enough to permit mastery of complicated patterns of skills and to accumulate really significant quantities of knowledge. Limited training periods do not allow sufficient time for the conceptual transformation of stable schema. This may be of little consequence for simple skills, which are characterized by low ability ceilings and probably require little modification of existing schema. It could be critical for abilities (whether or not possessed of important motor components) which require the acquisition of a lengthy series of interrelated verbal symbols and concepts.

McGraw's (1935, 1939) well-known, longitudinal training study of motor processes in twins is, for the length of training (2 years), rare among all studies of early learning, and unique for studies of motor development. Although the twins were fraternal, the trained twin's clear superiority in many skills over his control twin is significant. The latter received only 2.5 months of training which did not start until he reached 22 months of age. McGraw, too, found evidence that the contrast in ability was most marked in complex skills, such as roller skating, swimming, and riding a tricycle. Cognitive processes were presumably more involved in these than in the simpler skills like sitting, standing, and walking.

Gains in some skills were even permanent, up to the age of 6. These were skills where performance had reached a high degree of integration and mastery. They were also abilities not lost as a result of alterations in body proportions through growth. McGraw believed that the trained twin's roller skating ability, for example, was lost because alterations introduced new structural elements into the situation. In addition, the extensively trained twin developed better overall muscular coordination than his brother, suggesting the work of generalizing processes. He also became more confident than his control twin in all motor activities. Clearly, more longitudinal training studies along the lines of McGraw's design, but based on larger samples and greater refinement of methods and other variables are in order.

Verbal Memory

Longitudinal training has been as sparsely used for studying verbal as it has been for studying motor abilities. Burtt's (1932, 1937, 1941) unusual and widely cited experiment on early auditory memory is the single exception in this area. It is a study which lends itself to much speculation regarding the value of early verbal education. Beginning training with his infant son at 15 months, Burtt read drama in the original Greek (meaningless to the boy) daily until he was 3 years old. Reading one

20-line passage less than 1 minute per day, he covered a total of 21 different passages, 3 new ones being introduced every 3 months. At the age of 8.5, highly significant differences appeared in the ease of learning previously exposed passages over learning new material of the same kind. At 14, differences were still present although less sharp, while by 18 no differences were detectable. One wonders how much greater the son's progress would have been if meaningful passages had been used—such as simple stories geared in content and syntax to the child's level.

In a short-term memory experiment, but utilizing meaningful narratives, Foster (1928) presented 31 children aged 2–7 to 4–9 (above average IQ) with 10 daily repetitions of each of 9 stories in sequence. In this way 22 children learned 8 stories (of the 9) and 9 children, 3–4 stories. Even the younger children learned sizable portions of the stories. Although the quantity learned was correlated with both CA and MA, the *shape* of the learning curves was the same at all ages, except for a flattening during the final story for the younger children. This flattening may have been because teaching methods appear to have been more suitable to the motivations of the older children. Munn (1954) in his review of motor skills states that this has too often been the case. Munn found little or no evidence that learning ability (which he defined as the rate of learning) is greater at older ages, only that the younger start at a lower level.

These observations point to the desirability of beginning verbal stimulation early and following through consistently. They further indicate that methods suitable for stimulating children at their own pace and level need to be developed. It also would be useful to scale activities according to equal units of difficulty at all levels. The latter is a problem related to that of standardizing IQ tests according to mental age norms.

Two further investigations on verbal memory (digits and names of objects), namely, those of Gates and Taylor (1925) and Hilgard (1933) were designed to throw into relief maturational influences in development. Both investigators used subjects 4 years of age or older. The tendency for the effects of environmental factors to be obscured by the methodological characteristics of this type of design have been summarized in the previous section. It is only necessary to add that specific training again proved of definite value at all ages. The fact that the effects of practice were erased after a lapse of months, on the other hand, could reflect the narrowness and conceptual simplicity of the subject matter. Numerous experiments have shown that meaningless material is more difficult to recall than meaningful material (e.g., Osgood, 1953). Burtt's signal success with material of this kind, therefore, may be credited to the prolonged periods of training he used.

Language

The language area provides still another study where Gesell's twins were used. This study was also inspired by an emphasis on maturational factors. Strayer (1930) stimulated Twin T verbally (word-object associations and simple commissions) from the ages of 84–88 weeks (inclusive), while Twin C was confined to a similar but language deprived environment. Twin C was then given 4 weeks of equivalent language stimulation, during which time Twin T

experienced a normal speech environment.

Over 4 weeks of their training programs, C acquired a vocabulary of 30 words and T learned 23. But the difference in rate of learning was slight, 1.074 to .936 words per day, respectively, for their first 29 words. Moreover, in total vocabulary (35 for T versus 30 for C), sentence structure and pronunciation, T was perceptibly superior to C, following Ts only slightly longer but earlier training. Twin T also appeared to be gaining in rate over C toward the close of the training. The really critical variable is contained in the additional 5 weeks of general cognitive (though largely nonlanguage) experience, that C accumulated prior to beginning training. We must also reiterate our other criticisms of this kind of design, chiefly, (*a*) the fact that the major progress of both twins was obviously associated with their specific training and (*b*) the significance of training was not demonstrated effectively because it was too brief. This second point would have been more dramatically illustrated, for example, had T's training been continued for 6 months or more, while C was confined to a deprived or "average" language environment.

Dawe (1942) has contributed the only investigation using even relatively long-term language stimulation during the preschool years. She used older children, ranging from 43 to 82 months in age. Dawe also studied other aspects of cognitive learning which will be reported further on. Coming from a deprived, orphanage environment, the subjects' mean IQ was only 80.6 at the outset. Using matched controls of 11 pairs of children, Dawe gave the experimental group about 50 hours of training per child in language and general information concepts. Training consisted of viewing and discussing pictures, listening to poems and stories, taking excursions, and making simple observations. On nearly all cognitive measures the improvement of the experimental group over their controls was significant at the 1% level. This included language measures of mean sentence length and the Smith-Williams vocabulary test. Indices of intelligibility and complexity of organization of speech also rose, but not significantly. Considering that training was restricted largely to weekends and lasted only 3 months, compared to the children's 4–7 years of total life experience, gains were indeed sizable. Additional designs of this type but embracing younger children from more normal backgrounds and over longer time spans, should be carried out.

A study by Milner (1951) offers promising retrospective information on the value of early language experience. Taking those first grade Negro children who scored contrastingly high and low on a language development test, she compared the two groups with respect to measures of their social background. The high language scorers were found to have participated much more widely in adult family conversation and received more overt demonstrations of affection. Other analyses of preschool children's histories have also shown the importance of adult relations and other home variables for the development of children's language (Smith, 1935; Van Alstyne, 1929; Williams & Mattson, 1942).

Beyond the foregoing studies, interest has centered on reporting age "norms" for acquiring various dimensions of language. It usually has been assumed that these norms directly reflect age-linked, maturational levels

(cf. Chen & Irwin, 1946; Lewis, 1936; McCarthy, 1930; Smith, 1926). But developmental norms can as readily be subject to environmental as to an innate growth interpretation, although interpretations of the former kind are infrequent. To illustrate an environmental approach, Ames and Learned (1948) record that the biggest jump in the addition of new space concept words occurs between 2–2.5 years. Is it possible that cultural stimulation in these concepts typically increases around this age so as to produce this jump? If so, shouldn't we ask whether cognitive development in this and other areas could not further be enhanced at all ages by the introduction of programed stimulation?

Actually, from an environmental perspective, norms of language development in themselves constitute evidence of the educability of young children in symbolic and other complex conceptual relationships. Thus, Welch (1940a) reported that the greatest gains in abstract vocabulary occurred at the ages of 18–21 months and again during the fourth year. He noted (Welch, 1940b) that these periods parallel the periods of greatest vocabulary gain which Smith (1926) recorded. McCarthy (1930) observed that her 2-year-olds used a mean of .9% compound and complex sentences. Several studies (McCarthy, 1930; Shirley, 1933; Smith, 1926; Young, 1941) have found a mean sentence length of 2–2.5 words by age 2.5. The mean sentence length of Fisher's (1934) "gifted" group was 2.5–4 words as early as 18 months, rising with age thereafter. In sum, as the evidence shows, children learn to speak from about the end of the first year, from then on steadily multiplying the number of discriminations and generalizations they grasp of the language system (McCarthy, 1954). Language training appears to proceed systematically and functionally almost from birth. What then of the potential for mastering other cognitive systems, such as the reading process or time and number concepts?

There is reason to believe, moreover, that language achievement proceeds more rapidly than has modally been estimated in the past, making the preschool child's potential for early cognitive learning proportionally greater. Language definitions used and methods of vocabulary sampling (the chief language index) have both been responsible for investigators grossly underestimating the size of children's vocabularies at all ages (McCarthy, 1954). The chief errors have been failure to use an unabridged dictionary, and insufficiently representative sampling of many categories of experience (Williams, 1932).

Conceptual Processes and Intelligence (IQ)

Work concentrating on the nature and extent of the generalizing and abstracting powers of children's cognitive development has taken two main forms. One form has maintained a strong interest in the elaboration of theoretical constructs on concept formation, not infrequently bound to specific content areas. This form incorporates processes of learning through the use of such concepts as "assimilation" and "accommodation" (Piaget, 1952). However, it tends to define development within an abstract gestalt framework rooted in maturational stages. This line of study, as represented in the ideas and work of Piaget and his followers (cf. Piaget, 1926, 1928, 1930, 1952, 1955; Piaget & Inhelder, 1956; Piaget &

Szeminska, 1952) and of Werner (1957) is generally continental European in origin and character. However rich in ideas, the crude experimental design, sampling, and statistical procedures, and the almost gratuitous age generalizations are well-known. These, along with theoretical criticisms, have been discussed in previous reviews (e.g., Huang, 1943; Thompson, 1952; Wohlwill, 1960).

Piaget's theories of perceptual-cognitive development have nevertheless stimulated some research on perception (cf. Wohlwill, 1960) and on the nature of children's thinking (Thompson, 1952; Vinacke, 1951). Most of the findings (e.g., Deutsche, 1937; Oakes, 1946; Russell, 1940; Russell & Dennis, 1939) have reported little evidence to support Piaget's rigid and manifold classification of thought and emergent stages of development. Moreover, although formal logic is less characteristic of the younger ages, rationality is found at all ages and may vary with experience almost as much as with age (Braine, 1959; Deutsche, 1937; Oakes, 1946).

Unfortunately, the consequences of long-term training rarely have been studied in theoretically derived work on conceptual processes at the preschool level. The work of Welch is an exception. He not only formulated a theory regarding the nature and order of development of abstract concepts, but he made efforts to transmute his theory into testable research designs (Welch, 1946, 1947a, 1947b, 1948; Welch & Davis, 1935). His studies are not always carefully controlled nor clearly reported, however. Essentially, Welch conceived of each higher order in a conceptual hierarchy or system as based on generalizations gradually formed from characteristics abstracted from a preceding, lower order. In one study Welch (1940a) found that his 12 high average IQ children aged 21–26 months had acquired a mean of 1.16 first-order hierarchical concepts; his nine 27–33 months old subjects had a mean of 3.88. Second-order concepts appeared in his subjects around 3.5 years (Welch, 1940a; Welch & Long, 1940).

In one of his attempts at long-term training, Welch also tried without success over 6 months to teach genus-species relations to children 12–20 months old. Data on IQ and other indices are incomplete. Welch reports that the children's motivations became almost completely destroyed in the course of training. Welch's teaching techniques are often formal, however, although he does occasionally mention in some studies efforts to maintain a "game atmosphere." This formality is especially manifest in another experiment (Welch, 1939c) where some 500 repetitions were required to condition a child to associate a wooden plate with an arbitrary name "ate." This is probably a difficult, past tense concept for the retarded level of knowledge of his slightly low IQ institutional subjects. Even so, the age period of his subjects falls exactly within the one McCarthy (1930) describes (18–20 months) as characteristic for learning word-object associations. Moreover, it seems a little rigid to persist in presenting so excessive a number of repetitions with a single, arbitrarily chosen stimulus term. The use of terms which harmonized more with cultural experience and a little preliminary exploration of the children's existing level of knowledge seem to have been indicated.

Despite Welch's formality, he was able to teach some verbal generaliza-

tions with dimensions of size and color to children less than 2 years old (Welch, 1939c). As reported earlier, he was also successful in imparting simpler nonverbal concepts of size, form, and area through discrimination learning. The combined contributions of Welch seem to open a broad avenue of possibilities for research on early conceptual learning.

The second form of attack on children's generalizing processes has been the study of intelligence through mental age and IQ testing. Originating mainly in Europe with Binet and couched in some theory, this approach has lent itself admirably to American and British empiricism through its ready translation of theoretical propositions into measurable units of performance (Anastasi, 1954). The theoretical foundations of IQ tests (e.g., Stanford-Binet) have tended to languish accordingly.

A heavy interest in the nature-nurture of intelligence (IQ) has been accompanied by a massive accumulation of studies, however thin in definition the problem has remained. As these studies have been covered extensively in many reviews (Anastasi, 1958; Jones, 1954; Wellman, 1945; Wellman & McCandless, 1946; Whipple, 1928, 1940; and others), we shall concentrate principally on studies and problems directly relevant to our purposes.

The largest amount of work has consisted of cross-sectional studies of children and adults of all ages. In these studies, investigators have correlated IQ test performances and environmental indices (amount of education; parents' educational, occupational, and social class level; urban-rural differences; etc.). A multitude of relationships of this kind, often important, have been found. Their value may be considered only partially attenuated by the discovery of other associations which concede greater importance to heredity (e.g., between IQ scores of parents and their children). The basic problem stems from the fact that broad, background correlations throw insufficient light on particular environmental antecedent-consequent relationships.

Few studies of any kind in the IQ area have been designed with the precision necessary to illuminate these relationships. Some valuable information has come out of the work on identical twins reared apart, but it is based on sparse case data, usually obtained through the retrospective reports of biased informants. With radical and lifelong differences in their environments, twins have often shown marked differences in IQ scores in later years, up to as much as 24 points. In fact, twins have been found to differ in IQ almost in proportion to the degree of discrepancy experienced in cognitive features of their environments (Newman, Freeman, & Holzinger, 1937). Woodworth (1941), tallying data from existing studies, derived a correlation of .79 between differences in amount of education and differences in IQ scores.

Investigations on adopted children (mainly, Burks, 1928; Freeman, Holzinger, & Mitchell, 1928; Leahy, 1935; Skodak, 1939; Skodak & Skeels, 1949) provide another good though still imprecise source of information regarding evnvironmental influences on IQ scores. Many of the children were placed for permanent adoption when only a few weeks old and were sometimes followed regularly over many years. But IQ measures were not always taken during the early years and the kind of training the children received was never specified nor controlled. As a result, the effect

of experience, especially early experience, upon intellectual development remained essentially unknown.

Among other important methodological oversights has been the failure to consider the influence of prenatal and neonatal factors or of selective placement. In addition, sample homogeneity has usually been greater among the foster children than among their controls. These problems are discussed at length in other sources (Anastasi, 1958; Jones, 1954). The typical IQ correlations between foster children-natural parents have ranged from .4 to .5. But it is evident that these correlations represent inflated values due to selective placement and sample homogeneity of the foster children. These two factors also have minimized IQ correlations between foster parents-foster children, further obscuring the influence of the environment. Nevertheless, in the Skodak and Skeels (1949) longitudinal study of 100 foster children, the mean IQ difference between foster children (from the age of less than 6 months through 13 years) and their natural mothers remained consistently at about 22 points. This is a sizable difference to persist in the face of methodological factors conceivably working in an opposite direction.

Historical surveys of "gifted" children, if again more descriptive than precise, have furnished additional, important clues on the function of early cognitive stimulation (Cox, 1926; Davidson, 1931). The association between cognitive precocity and the application of intensive stimulation from infancy has always been impressively high. This suggests a need for revising the concept gifted, since it is so heavily weighted in favor of heredity alone.

In fact, this writer has managed to assemble from various sources a sample of 25 superior IQ children, all of whom learned to read by the age of 3 (Cox, 1926; Davidson, 1931; Dolbear, 1912; Hollingworth, 1926, 1942; Jones, 1923; Root, 1921; Stoner, 1914; Terman, 1917, 1918, 1924). Of these, 72% had definitely enjoyed a great deal of unusually early and intensive cognitive stimulation. For the other 28% evidence regarding the quality and quantity of stimulation was lacking in the records.

Where long-term training has been used at all, most programs have taken the form of nursery school education. These usually have been broad and uncertain in meaning and have seldom concentrated upon verbal development, an important component of many IQ tests (Anastasi, 1958; Wellman & McCandless, 1946).

It is worth noting that studies which have measured IQ changes associated with nursery school experience by means of the Merrill-Palmer scale have regularly shown greater IQ improvements than studies using some revision of the Binet scales (Wellman, 1945). In a Binet measured group of some 1,537 children from 22 nursery groups, the mean increase was 5.4 IQ points, compared with .5 points for the controls (597 children in 14 groups). Using the Merrill-Palmer scale, investigators found the improvement in 267 children in 7 nursery groups amounted to a mean of 14.5 points; 73 nonschool controls in 4 groups registered a mean increase of only 6.7 points. It appears reasonable to attribute some of this difference to the similarity of most Merrill-Palmer test items (pegboard, picture puzzles, block building, etc.) to nursery school type activities, while Binet items consist of a greater proportion of verbal items, even at the youngest age levels

(Anastasi, 1958). Bayley (1949), too, observes that many Merrill-Palmer test "items test motor skills rather than insightful behaviors" (p. 228).

These characteristics of nursery school programs may further help to explain why high IQ scorers gain fewer points than low or average scorers do (Anastasi, 1958). Bright children have probably already mastered much of the relatively limited range of nonverbal, cognitive material offered in nursery programs.

In the same vein, Klatskin (1952) studied the effects of good pediatric care and permissiveness in child rearing upon Catell IQ test scores. Her group of 184, 1-year-old infants surpassed test norms, *except* on verbal and some fine-motor type items.

Even when training programs are used whose orientation is clearly cognitive, however, a problem of measurement still remains. Our instruments for measuring "intelligence," IQ tests, especially those for younger children, are relatively crude, unreliable, and theoretically undefined (Anastasi, 1954). In many cases, they yield only a composite index, based on a loose mixture of verbal and nonverbal tasks, neither logically related nor organized into *types* of abilities. Understandably, there has been little accurate information collected on the patterning of preschool children's abilities, not to mention relating variations to differences in types of training. For example, even with the less verbal Merrill-Palmer scale, the learning which is measured is not easily traceable to specific nursery activities. Barrett and Koch (1930), found score increases in particular test items occurred more or less without relation to the frequency of participation in certain activities in the school. In this instance, it appears that the standardization procedures used were partly responsible, since the test tended to overrate younger subjects increasingly to a point and to underrate older ones.

These limitations of preschool tests may also partially answer why correlations between the performances of preschool and older children on IQ tests remain persistently low (J. E. Anderson, 1939; L. D. Anderson, 1939; Bayley, 1949, 1955; Honzik, Macfarlane, & Allen, 1948). Not only is the reliability of preschool tests per se low, but even the Binet contains fewer cognitively weighted items for the younger years. Our instruments measure somewhat different abilities at different ages. This is no doubt a by-product of our traditional propensity for deriving IQ measures empirically on the basis of internal consistency and age progression (Meyers & Dingman, 1960). The spectrum of abilities measured also narrows with age.

It is all the more interesting, therefore, to find that, despite the poor specification of both training and IQ tests, nursery school attendance has consistently produced small to moderate increases in IQ scores (Anastasi, 1958; Wellman, 1945). This has been truer for children of less than superior ability, and is apparently based more on perceptual-motor than verbal learning.

Of all the many studies of IQ, only four have developed long-term programs of general cognitive stimulation for preschool children. One of these is a study in progress by this investigator on three pairs of identical twins and a set of triplets. Two studies included no children younger than 43 months of age. In one study, Dawe (1942) followed the progress in language and general cognition that 11 children made over 3 months of

weekend training. Details of the investigation were reported in the section on language. In addition to language gains, her subjects made significant mean gains in Binet IQ scores (14.2 points against a 2-point loss for the controls) as well as in other cognitive measures, i.e., science and home living information.

McCandless (1940) attempted to raise the intellectual level of 6 very bright (139 IQ) preschool children by means of an enriched curriculum supplementing the regular nursery school program. The children's mean age was about 52 months. The program consisted of project work (constructing a farm and a combination flower store-hotel) presented over much of 1 school year. Initial posttest differences in IQ scores (1916 Stanford) between the experimental group and their matched controls were not significant. However, retest differences the following fall reached significance on the newly revised (1937) Stanford. The retest shift was attributed mainly to the nature of the 1937 test revision, which corrected for the decline in age associated with the 1916 Stanford. These results may appear more impressive when one questions just how stimulating this kind of project work could be for children already of high ability—particularly given the Binet's heavy use of verbal symbols by this age.

Peters and McElwee (1944) furnished 8 months of guided play to 6 young subjects (aged 2–9 to 4–2) of below average IQ who attended nursery school three mornings per week. Activities were organized according to categories of "functional intelligence," although the amount of verbal stimulation offered is not clear. Home visits and conferences with the mother were also included. Although there were no controls, children registered a mean gain of 7 IQ points. While not statistically significant (.07), this included one child whose score fell as a result of obvious motivational distraction during posttesting. Taking these three studies together, their relatively well outlined and lengthy cognitive educational programs contain many implications for education and the meaning of IQ measures.

The extensive work done on intelligence in relation to the nature-nurture problem has been the subject of vigorous discussion and conflicting findings over many years (cf. Anastasi, 1958). But one regrettable consequence has been the manner in which arguments over the relative importance of heredity and environment have obscured the fact that the environment does perform an *essential* role in development. It is difficult to argue, considering all the evidence, that environment has a *negligible* role in producing mental test variations or in developing intelligence and conceptual abilities, however important genetic factors may also be. The dispute has seriously retarded interest in experimental work on preschool cognitive learning. It also has discouraged long range educational programs aimed at developing each child to near the maximum level of his capacities.

Special Cognitive Processes

As to be expected from the evidence considered so far, there is no particular cognitive category which has generated much research interest. This applies equally to all symbol or language systems, exemplified by the areas of reading, mathematics, and music. Yet, until the late 1800s it was common practice in Western culture to begin instruction in the

"three Rs," reading, writing, and arithmetic, as early as age 2 or 3 (Adamson, 1905, 1930; Brown, 1924; Parker, 1912; Raymont, 1937; Ward, 1901).

Few careful investigations have come down to us but reports are clear that schools were few and learning limited, even at the older ages (Adamson, 1905, 1930; Birchenough, 1920; Rusk, 1933; Salmon & Hindshaw, 1904; Smith, 1931; Stow, 1859). This is hardly surprising since, at all levels of the infant (ages 2–7) and grammar school systems, many serious deficiencies prevailed which persisted well into the last half of the nineteenth century (Birchenough, 1920; Forest, 1927; Raymont, 1937; Rusk, 1933; Salmon & Hindshaw, 1904; Stow, 1859). Curricula were narrowly restricted to religious dogma and the tool subjects (the three Rs), often making use of unsimplified texts, including above all the Bible itself. Authoritarian discipline, enforced by harsh physical punishment, was the rule. Teaching methods were rigid and tedious, being based on rote learning through incessant drill on isolated elements. The lecture system was used freely, making little concession to age differences. Enormous classes were characteristic. Infant schools typically confined immobile for hours from 50 to 200 and sometimes as many as 1,000 undernourished children, crowded into galleries. They were watched by the petty, severe, and ignorant eye of monitors only slightly older than the children. Over such a mass only one or two adult teachers presided, who were poorly trained, if at all.

It is almost astonishing therefore, to discover that a number of even the youngest children apparently learned to read, write, compute, and acquire general knowledge to the extent they did under such primitive conditions and techniques. Moreover, accomplishments appear to have been quite extensive wherever conditions were ameliorated. These better schools and tutorial situations were unhappily restricted almost entirely to children from the wealthier classes (Adamson, 1905, 1930; Birchenough, 1920; Brown, 1924; Parker, 1912; Reisner, 1930; Rusk, 1933).

In any case it was in reaction to the generally harsh conditions that, over the nineteenth century, the ideas and methods of Rousseau, Pestalozzi, and especially Froebel took hold. They became major sources from which the kindergarten and the nursery school "movements" were formed, leading to a gradual revolutionizing of school systems at early childhood and other levels (Raymont, 1937; Salmon & Hindshaw, 1904; Smith, 1931).

Child centered programs and permissive guidance techniques concerned with the rounded development of children in socioemotional and sensory-motor spheres were substituted for academic, subject centered curricula. These and other educational philosophies as well as the concepts of molar, developmental, and dynamic psychology later contributed many other specific influences. Feeding these philosophies have been the ideas of Freud, Montessori, Dewey, Gesell, and gestalt psychology, in addition to pressures from periodic reform movements. In this way, wretched conditions, authoritarian discipline, and rigid methods have been slowly replaced.

Possibly the last major institutional effort to include a cognitive emphasis at the preschool level occurred in the early 1900s. Montessori

(1912) organized a number of schools which combined the new, child centered principles with the ancient subject-matter orientation. These were highly successful in teaching children as young as 4 years old to read and write, and to acquire a broad array of simple concepts. Since that time, formal cognitive education in early childhood has ceased to flourish (Raymont, 1937; and others). It exists now only in those isolated instances where preschool children continue to be taught formally in scattered private schools (usually 4-year-olds in kindergarten) or informally in a home setting.

Reading Ability

Nearly all cases of early reading come to light from historical sources or from surveys of gifted children. Information is most detailed in the accounts of children taught individually in the home by tutors, parents, or other relatives (Cox, 1926; Davidson, 1931; Dolbear, 1912; Hollingworth, 1926, 1942; Root, 1921; Sidis, 1911; Stoner, 1914; Terman, 1918; Witte, 1914). These accounts prove to be one of the best stimulants for encouraging research on cognitive learning in early childhood. Methods are sometimes fairly well described. Much of this early childhood education has been devoted to general knowledge, and many "home educators" have shared a strong belief in intensive education from birth as a *sine qua non* for the ontogeny of high intelligence.

Winifred Stoner (Stoner, 1914; Griffiths, 1923) was given a carefully graduated program of reading and wide general knowledge by her mother from the age of 6 months on. By 16 months she could read and spell, by 2 years she could write. No definite degree of proficiency is specified until age 3, when she had reportedly acquired much skill in all and was beginning to typewrite. The child otherwise participated actively in physical and dramatic peer play and from childhood on experienced much school and some literary success. Although a controversial lay educational figure, the mother enjoyed considerable support from professionals. Her reading instruction methods (Stoner, 1914, 1916) in some ways typical of many home educators, consisted primarily of synthesizing words, using phonic principles, along with reading simple texts. Letters were presented initially in enlarged, colorful cutout forms and learning was further reinforced through an endless variety of songs, plays, games, and stories.

The case of Viola Olerich (Dolbear, 1912) is of interest in that she was adopted at 8 months by a professor, Olerich, expressly for demonstrating his ideas on the early development of abilities. He succeeded in teaching the child to read by a sentence method shortly after the age of 17 months. By the age of 2–11 she could read with "force and suggestion" almost any reading material presented to her.

An earlier illustration is furnished by a German clergyman, Witte (1914), who, before the son's birth in 1800, predicted the high intellectual abilities which his son later acquired with the help of painstaking programing from infancy. The child learned to read and spell fluently well before 5, through an alphabet-phonic method. He also became an exceptionally thoughtful and well-informed, yet modest child. Attaining his doctorate easily at 14 he later rose to eminence as a leading university scholar in literature.

Many other examples of preco-

cious readers could be cited. Some of these, like Macauley, John Stuart Mill, Francis Galton (Cox, 1926; Terman, 1917), and Norbert Wiener (1953), came to be renowned thinkers of their time. All of them experienced intensive cognitive education from the earliest years.

Experimental investigation of early reading is restricted to some five studies,[2] plus a sixth on which this investigator is working. Of three early studies, Davidson's (1931) study on 3-, 4-, and 5-year-old children was the most extensive. The children were divided by age and ability into 3 groups of 4–5 children each, all having an MA of 4 years. The mean IQs of the respective groups were 128, 98, 77 on the 1916 Stanford.

Four months of individual and group reading instruction were offered 10–15 minutes daily in a morning kindergarten type program. A word-sentence method was used, with the aid of play activity, motivating techniques, but drawing some attention to structural detail.

In the course of training, nearly all children made definite headway in learning to read simple primer material. Two of the bright 3-year-olds covered the equivalent of a first grade program in less than half a school year and were rapidly becoming fluent readers. Moreover, at least one (with signs of another) of the 4-year-olds of average IQ was on the verge of fluent reading, while one dull 5-year-old was making substantial progress.

An outstanding feature of this experiment is that these results were obtained even with average and low IQ children well before the usual school age of 6. Another is that mean IQ increases of 9.2, 9.75, and 10.75 points were obtained by the respective 3-, 4-, and 5-year-old groups over so relatively brief a period. Still another emerges in the fact that extensive cognitive stimulation at home (almost daily parental story reading) had been experienced only by the best readers (all four bright 3-year-olds). In contrast, only one other child had been read to more than occasionally—and she was the most successful 4-year-old reader.

In another early study, Brown (1924) experimented on short-term word training (nouns only) with 12 children, aged 3–6 to 5–11 and with another child of only 22 months. She followed a stencil-tracing method, together with the use of printed flash cards, posters, and a primer, sustaining motivation by the use of games. Two children, a girl aged 3–10, whose IQ was only 91, and a boy of 3–6, whose IQ was 140, were given 20- to 30-minute individual reading lessons in their homes, 5 days a week for 3 months.

> Catherine, in 36 lessons, learned to read 11 pages of her primer. Roger in 26 lessons, reached the same point. Both children could read their charts, and the recombination of words upon the charts, with perfect ease (Brown, 1924, p. 135).

With respect to short-term word learning, even the child of 22 months, whose IQ was only 118, learned to discriminate three words in only five lessons. She still recognized them 3 months later.

One of the most remarkable and successful experiments in early read-

[2] The paucity of interest in this area, especially on the part of psychologists, is underscored by the fact that three of these studies were all performed at one place, Stanford, more than 30 years ago (Brown, 1924; Davidson, 1931; Terman, 1918), one of which was a report by Terman on an experiment by a parent; and the fact that, of the other two (Fowler, in press; Moore & Anderson, 1960), one is by a sociologist (Moore & Anderson, 1960).

ing was performed by a lay educator. It is included here because of its unusual verification and documentation, reported by Terman (1918). This anonymous father began to teach his daughter, Martha, to read from the age of 14 months, when her speech was limited to just three words. He first taught her the capital letters, so that the child's fourth spoken word was "pretty B" (pretty, being the third). Otherwise he followed a sight word method, employing play oriented techniques and fabricating simplified sentence charts.

Success was far from immediate, however. The next five months were passed primarily in teaching the child word-object relationships. Apparently, at 19 months certain important concepts developed, for Martha rather suddenly in 1 month rapidly mastered, first, all capital then the small letters. At 21 months and 10 days, with a reading vocabulary of 35 words, she made some generalization to the effect "that these word pictures represented thoughts" (p. 223) occurred. At 23 months Martha "began to experience the mental pleasure of reading," (p. 225) and had acquired a reading vocabulary of 150 words. By 26.5 months, she had covered 4.5 primers, embracing a vocabulary of over 700 words. She could read fluently and meaningfully, but her pronunciation was less perfected.

This case is unique in providing well-verified evidence of how a child of not more than 140 IQ and MA of just 3–0 years (extrapolated from a 1916 Stanford given at age 3–11) learned to read.

Of the three recent investigations, complete data is available only on one, an extensive monograph by Fowler (in press). He reports on a 9 months' exploratory effort to teach his 2-year-old daughter, Velia, to read, experimenting with a combination of methods in a trial-and-error, but carefully regulated approach. Stimulation averaged 30 minutes daily and was freely immersed in dramatic play and family routines.

During the program the subject accumulated an out-of-context, recognition vocabulary of about 250 words. Words tested had not been exposed to the subject for a mean of 18.5 days and were recognized with about 87.3% accuracy. Toward the end Velia could read meaningfully a few isolated, primer type sentences, 2–5 words in length. She was also beginning to read preprimers, and could perceive words with increasing precision using phonic cues.

The child had also experienced a planned, broad program of intensive cognitive stimulation from her earliest weeks. This experience is believed to have been a major factor developing Velia's IQ to the high range (150–170) within which Velia scored on all tests from age 2 to 8. Moreover, in preliminary pilot work, she learned to identify with ease all capitals at 21 months and most small letters by 23 months.

Among techniques and dimensions explored at some length were dramatic play, reinforcement procedures, phonics, whole-word learning, and the effect of varying type style and size. Picture-association and various other materials and methods of presenting stimuli were similarly experimented with.

Follow-up tests and observations to age 8.5 have repeatedly revealed Velia to be reading avidly with comprehension and facility 2–3 grades above level. In addition, she continues to pursue enthusiastically a wide variety of other cognitive and social interests. It is worth recording

that she is less advanced in certain cognitive areas, e.g., arithmetic, where she has received little special stimulation. Emotional problems are covered separately under psychosocial development.

Investigations in progress by Moore and Anderson (1960) on early reading and writing, are as yet published only in film form. From limited information,[3] it appears that several children, aged 3–5, have made definite progress in learning to read and write. One child, who started at 2–7, apparently reached a second grade level 6 months later. Of special interest is their method involving the use of an electric typewriter (using correct fingering), which probably enhances motivations as well as facilitates learning.

Studies of reading instruction in the field of education have contrastingly, in contemporary times, been mostly restricted to grade school children. We find only an occasional study of reading (readiness) gradients, for instance, which descends to the preschool years (e.g., Ilg & Ames, 1950). Despite prevalent use of the concept of "reading readiness" (or, generically, "learning readiness"), which *theoretically* allows for wide individual differences in the age, rate, and facility for learning to read, instruction in *practice* is basically linked to age norms. Reading continues to be introduced at 5–7 years of age for almost all children, regardless of ability, when the child enters elementary school (unless he is taught at home) (cf. Betts, 1957).

Aside from the role of recent traditions, this practice parallels a predominant educational view (cf. Anderson & Dearborn, 1952; Dolch, 1955; Gates, 1937; Monroe, 1951; Morphett & Washburne, 1931). It is widely asserted that children experience difficulty in learning to read below a certain MA level, usually figured at about 5–7 years.

Taking a longer time span, the paucity of interest in early reading and cognition also may well be a by-product of theoretical viewpoints relating to the nature of the young child's emotional development, as we shall discuss shortly. These views are believed to have arisen as part of a strong and persisting historical reaction to the traditional authoritarian and rote methods of education described earlier.

Both the evidence we have presented and Davidson's (1931) survey, on the other hand, indicate that, historically speaking, many 4-year-olds (MA) have learned to read fluently. Moreover, an estimate by the writer, based on data compiled from studies of intellectually superior children (Barbe, 1952; Cox, 1926; Davidson, 1931; Hollingworth, 1926, 1942; Ilg & Ames, 1950; Miles, 1954; Terman, 1924, 1925; Witty, 1930, 1940), suggests that perhaps .01% of the general population learns to read as early as 4 years (CA). Many of these children are ordinarily classified as gifted, but where records are adequate all precocious readers received a great deal of prior stimulation. Consequently, to label a child as gifted in no way dispenses with the necessity of stimulation—if he is to learn. However genetically bright a child may be, development does not proceed by maturation alone. It should further be re-emphasized that both Brown (1924) and Davidson (1931) made real headway in teaching even 3- and 4-year-olds of average IQ how to read, while Davidson made progress with low IQ 5-year-olds. In

[3] O. K. Moore, personal communication, 1961.

sum, it would appear that in the theory and practice of educating young children we have been missing both the MA and CA marks by a sizable margin.

Mathematics

Because of its specialized subject matter and symbol systems, mathematics is relatively independent from other branches of knowledge. In arithmetic, this peculiarity has been considered one reason for the development of certain precocious "wizard" calculators (Révész, 1940). These bizarre children often have been contrastingly undeveloped in other areas, including general mathematics itself. In extreme form, one-sided prodigies have been termed "idiot savants." The phenomenon also is found in musical abilities and sometimes in drawing, mechanics, memory, or motor coordination (Barlow, 1951; Rife & Synder, 1931; Tredgold & Soddy, 1956). On the other hand, many mathematical, reading, and musical prodigies have been well-rounded in ability. Usually, the mathematical prodigies have excelled in mental arithmetic and many of them apparently began their training prior to age 3 (Barlow, 1951; Bell, 1937; Mitchell, 1907; Rife & Snyder, 1931; Scheerer, Rothman, & Goldstein, 1945; Scripture, 1891; Tredgold & Soddy, 1956). According to Mitchell (1907) and Révész (1940), precocity has been the rule for prodigious calculators, exceptional ability usually being identified at about 5–5.5 years in 75% of the cases.

Unfortunately, little is known of the environmental origins of these abilities, especially concerning higher mathematics. Even less is available on teaching methods, beyond occasional comment, for instance, that a boy putatively learned by counting pebbles or peas as a means of passing the hours while tending sheep. The prevailing genetic orientation of earlier investigators may be partly responsible for this lack of interest in the details of learning. A useful exception is provided by Stoner (1914, 1916), who reported that her child could, for example, count change by age 2. Stoner furnishes ample detail on teaching procedures, most of which call for games and similar motivating devices.

The frequent unevenness in acquiring abilities also may be explained as a contrast phenomenon. Perceptually, this would inflate gains achieved in one (or two) successful areas, when found in an individual of otherwise low abilities. The retrospective basis and sketchiness of most case records would tend to promote this effect. On the other hand, the observed disparity in well-documented cases has led to a number of theories, nearly all of which accord some place to experience. Some emphasize the unequal inheritance of abilities; others stress that pathology (emotional and/or organic) may be implicated (Scheerer, Rothman, & Goldstein, 1945). What may be forgotten is that the extent to which environmental factors can develop abilities unequally is a measure of the degree to which abilities can be learned independently of one another.

That long periods of learning are indispensable for the early acquisition of calculating and similar abilities is suggested by the following: case records, although often less complete than those on early reading, similarly point to years of exceptional, early stimulation and practice as the rule (Bell, 1937; Jakobsson, 1944; and others). Second, there is much evidence to suggest that the preschool child's successful efforts to attain

high abilities have frequently been early and liberally reinforced and channelized by such social role labels as "wizard" or "genius" calculator (Barlow, 1951; Mitchell, 1907; and others). Finally, it is unreasonable to believe that even the "simpler" mathematical concepts, thousands of years in the attainment historically (Sarton, 1952, 1959), could emerge autogenously in untutored children, following Dennis' and Dennis' (1951) notion.

Yet even contemporary research on the numerical abilities of preschool children, as in other cognitive areas, is still highly concentrated on merely registering the ages and order of normal development. It is as if the development of abilities does indeed evolve autogenously or through maturation alone. In fact no experiments were found which were directly concerned with how, or the degree to which, preschool children can learn quantitative relationships and numbers. Nor do educational theory and practice make any provision for teaching arithmetic before age 5, any more than they do for reading. Similarly, MA concepts of arithmetic "readiness" have, for elementary school programs, been interpreted rigidly in terms of age norms (e.g., Harding, 1959; Washburne, 1928).

The observations of Ilg and Ames (1951) illustrate this maturational outlook. Developmental gradients on several aspects of the number process at 6-month intervals from the age of 1 year through 9 years have been catalogued. In their usual fashion little attention is devoted to learning processes, mental growth being the descriptive framework. Similar collections of developmental observations on number concepts in early childhood have been assembled by Descoeudres (1946), Giltay (1936), and Long and Welch (1941). Piaget and Szeminska (1952) have also worked in this area, although they are more concerned with theory than with facts. Probably the most important modal shift in the acquisition of number concepts involves moving from simple perception of "oneness" and "twoness," or broad discriminations of quantity, to comprehension and accurate perception of three or more units. This takes place usually around the age of 3.5. But nearly every study finds some children who make this basic transition toward functional mastery of the number system at the age of 3 or younger (and some at older ages). Therefore, unless the explanation is assumed to be totally a genetic one, the now unprobed differences in learning opportunities should be investigated. This point is brought into sharper relief by Ilg's and Ames' (1951) observation that adding behavior begins primarily at 5 and 6, precisely the ages when most children enter elementary school.

Musical Ability

Like mathematics, musical structure is also comparatively independent of other categories of cognition. Music, too, has frequently been learned early. But until the inception of the kindergarten movement, music, unlike the three Rs, was never prominent in most infant school programs (Adamson, 1905; Raymont, 1937; Reisner, 1930). As a result, source material on the early development of musical abilities is largely biographical (e.g., Barlow, 1951; Bowerman, 1947; Maazel, 1950). The records show that the family (or tutors) has been the primary agent for musical education, at least until later in childhood. Teaching methods although seldom adequately de-

scribed, have often been surprisingly formal from a very young age. Stoner (1914, 1916) in the music field was one of the innovators in deviating from this formality, which of course simply paralleled the rigor traditionally used in all instruction. She adapted both vocal and instrumental (violin) learning to her young daughter's levels of development, cognitively and dramatically. As we shall see from a survey of musical child prodigies, much early stimulation has taken the form of immersion in a rich musical milieu. But formal or informal, no early achievements are recorded (where records are detailed) without unusual stimulation having preceded these accomplishments.

To mention a few well-known examples (Maazel, 1950), Mozart, born into an intense family musical atmosphere, began playing at about 3 years, receiving formal lessons at this age. He began composing as early as age 5, attracting public attention soon after. Yehudi Menuhin was performing as a violin soloist with the San Francisco Symphony by 6; he had begun lessons formally at 3. Mendelssohn played in public at 9 and composed fluently at 11; he had begun formal piano instruction at age 4. Josef Hofmann started lessons at 3.5 and performed in public at 6. Haydn began formal lessons at 5, having been exposed earlier to much informal stimulation, and was able to sing many songs from an early age. Jascha Heifetz accompanied his parents to concerts from infancy, took lessons formally from the age of 3 and played his violin in public by 5. Sandra Berkova displayed little sign of musical talent prior to beginning systematic violin instruction at 2.5 with her mother, herself a concert violinist. Berkova played her first concert (of 14 pieces) at 3.5, making a debut with the Los Angeles Symphony at 5. Both Heifetz and Berkova learned with the aid of an interesting teaching device; they played initially on a miniature violin (not a toy), fabricated to their size. Among many other cases which could be cited, Gaw (1922) reports a child who could hum tunes at 1 year and sang publicly at 4. She started piano lessons formally at 5 and later became a concert accompanist. Paralleling other accounts where reporting is complete, this child was exposed to constant musical activity practically from birth.

There also has been some experimental work done on the early development of musical skills, although less than on early reading. Curiously, there have been fewer efforts to tabulate developmental norms for this area. In one such tabulation, however, Jersild and Bienstock (1934) concluded that many children as young as 4 have developed such abilities as, for example, being able to sing a range of tones equal to those of the average adult. Two studies (Gaw, 1922; Stanton, 1922) at Iowa surveyed musical ability in the schools, using the Seashore measures of musical talent. Both were concerned with weighing the relative contributions of heredity and environment. Data were restricted to frequencies and percentages compiled from rather incomplete and retrospective case material. Although the authors drew conclusions in favor of heredity, inspection of the data reveals that the same pattern of findings is easily consistent with environmental explanations. The association between the children's abilities and their musical experience was poorly controlled.

Four experimental studies, two of

them well controlled, have succeeded admirably in teaching young children vocal abilities. Jersild and Bienstock (1931) taught 18 children from 30 to 48 months of age to sing songs 10 minutes twice weekly over a stretch of 6 months. The experimental children scored significantly higher on pitch and intervals tests than their untrained controls. Four months following the training, the practice group was still very much in the lead. Updegraff, Heiliger, and Learned (1938) report similar, highly positive results for their controlled study. Jersild and Bienstock (1934) later gave only 6 weeks training to 23 children aged 3–8.5 years, but used no controls. They reported that some permanency of gains was retained over a 2-year period. They conclude from their several studies that early training is advantageous to musical ability. If ability is not learned early, they believe "habits of disuse" may occur which inhibit learning at older ages.

Hissen (1933) in a similar study produced evidence that children aged 21–54 months improved in tonal discrimination and accuracy of tonal reproduction with training lasting from 1 to 2 nursery school semesters (10–20 lessons). In one experiment, Colby (1935) failed in teaching 3.5–4 year old children to play a tin fife, in part because the fingers of the young children were too short for the instrument. Fabrication of a miniature instrument, equivalent to the violins of Heifitz and Berkova, might have resolved this difficulty.

Musical abilities in early childhood have been only superficially studied. There are nevertheless many positive findings, both historical and experimental, on benefits of early, long-term stimulation. Extensive experimental work is necessary to substantiate and expand these findings and to establish a pool of information on techniques of musical training.

Drawing and Painting

The medium of drawing is perhaps not ordinarily thought of as a cognitive process based on symbols and abstract concepts in the same way mathematics and conventional language are. This may be because, in addition to being classified as a less definable artistic or creative activity, the finished product has often tended to "look like" our visual perception of an aspect of reality. The fact of selectivity and the existence of techniques and rules for realizing different modes of expression in art work, however, point to the involvement of abstract, symbol systems (Robb & Garrison, 1935). Techniques for handling 3-dimensional percepts on 2-dimensional planes or for handling problems of chiaroscuro are, for example, highly complicated. The wide range of differences achieved in ability levels further suggests the complexity of learning implicated (whatever the role of inherited talent). It is, moreover, probably for these reasons that drawing tasks have been utilized in several IQ tests (e.g., Goodenough, 1926; Jaffa, 1934; Terman & Merrill, 1937). But, as we have indicated, rules and methods for learning to draw and paint, are usually less formally defined or widely agree upon than, say, those for the structure of mathematics and music. This absence of formal definition may help to account for the dearth of reports on precocious painters found in historical sources.

Most research on drawing ability and related visual art forms has over many years (Goodenough, 1926)

rarely stepped beyond an interest in describing typical developmental sequences. Monroe (1929), for example, has chronicled a series of stages of progression, starting at age 2, along a continuum of the degree to which the child has learned to represent reality in his spontaneous drawings. In general, drawing as a more complex conceptual process tends to emerge (according to the norms) around the age of 3, when the child begins to draw ideoperceptual forms planfully as opposed to the random production of scribbled lines and loops. Goodenough's (1926) MA and IQ test is based on the extent of complexity and realism the child utilizes in drawing the figure of a man, but descends only to age 3.5. Gesell and his followers (e.g., Gesell et al., 1940; Gesell & Ilg, 1949) have included drawing skills in their collections of developmental norms. Thus, for example, Gesell and Ames (1946) find certain directions prevail in the way a child draws at a given age.

Dubin (1946), on the other hand, was successful in accelerating the mean development of a group of nursery school children in representational drawing abilities during a period of about 6 months of special training. The children ranged in age from 2–0 to 4–8 years, with a mean of 3–3 years. They were classified according to Monroe's (1929) "stages" of drawing development. Each child was stimulated to achieve beyond his present stage of skill in easel painting, by means of open-ended questions or statements of encouragement. Differences in favor of the experimental group over their matched controls (who engaged in 6 months of undirected drawing) were significant at the 1–2% level. Interest of the children in drawing also increased significantly.

Results in this case are promising but the experiment is isolated and historical evidence limited. Without further research few conclusions can be drawn regarding the possibilities of early learning in this area.

Writing

Writing is closely related to drawing, in the sense of some of the perceptual-motor skills composing it. The chief difference lies in the obvious substitution of intricate verbal-symbol systems for the visual imagery and forms of drawing.

As always, the empirical search for developmental age trends, based on maturational assumptions, is the preferred investigational approach. The studies of Ames and Ilg (1951) and Hildreth (1936) illustrate this approach. The developmental norms reported coincide with the age period when the child enters the formal school system. As might be expected, the biggest jumps in the accurate production of letters and words generally occur during the sixth and especially the seventh years.

Although writing was one of the three Rs in the early infant schools (Adamson, 1905; Brown, 1924; Rusk, 1933), it may not have been given as much attention, since details are so little reported in historical sources. We know only of Stoner's (1914) daughter, who could write and spell simple sentences before she was 2, and the case of Francis Galton (Terman, 1917). Galton had learned to write simple prose by his fourth year, through the painstaking but gentle efforts of his older sister.

Montessori's (1912) success in teaching 4-year-olds to write in her nursery schools also needs reiteration, especially in the light of her detailed accounts on method (1912, 1920). She first had the children

finger-trace raised abstract-geometric forms which had been treated to make a rough, sandpapered surface. This was followed by the gradual introduction of similarly fabricated, raised letters. Montessori found that, within a few weeks, children as young as age 4 began to write, in her terms, "spontaneously." Progress was almost invariably rapid from this point on.

Montessori's pioneer investigations on early cognitive learning have fostered no continuing interest, unfortunately. But there is some recent revival of interest reflected in the preliminary work of Moore and Anderson (1960), cited earlier; also a study of this investigator (in progress) on a 3-year-old learning to write. Assuming more extensive confirmation with other subjects, the relationship of these early childhood writing achievements to norms like those of Ames and Ilg (1951) and of Hildreth (1936) is clear. Established with little reference to prior training, these norms should probably be restricted in definition to one of cultural norms arising from prevailing practices.

Early Cognitive Stimulation and Psychosocial Development

There is current a widespread belief that to undertake extensive cognitive stimulation with the infant and young child is to invite frustration, learning inhibitions, and, in more extreme form, general personality disturbances. Much of the foundation for this opinion is unquestionably rooted in concern over the emotional problems which are supposed to have been generated in traditionally rigid educational systems. There is also an ancient popular belief that abnormal development ("madness") is a concomitant of extreme mental brightness ("genius") and early prodigy. Scholars have, in the past, lent some credence to this notion (Lange-Eichbaum, 1931; Lombroso, 1891). The basis for this latter view, if not the view itself, has been seriously weakened in recent times. There is now a plethora of studies demonstrating that intellectually precocious children enjoy above average social adjustment, as well as intellectual achievement, throughout their life span (Cox, 1926; Davidson, 1931; Hollingworth, 1926, 1942; Miles, 1954; Terman, 1918, 1925; Terman & Oden, 1940a, 1940b, 1947; Witty, 1930, 1940).

Contemporary psychological theory is nevertheless inclined to regard emotional damage to the child as an inherent consequent of the process of systematic (if not all) early training in cognition. Developmental and psychodynamic theory especially defines the nature of the young child as rather fragile, autistic, and irrational—at the mercy of his emotional life. It is also believed that he lacks perceptual-cognitive structure, objectivity, and basic concepts essential for assimilating cognitive stimuli to any important degree. Many stress the importance of neural immaturity, requiring that certain stages of structural "ripeness" be attained before complex categories of intellectual stimulation can be absorbed safely. To some extent these beliefs are intrinsic to the widely held concept of "learning readiness," although the notion of "timely" stimulation which should not come too late or too early is common (cf. Betts, 1957; Monroe, 1951; Thompson, 1952; Witty, 1946). The young organism also is often considered to be governed by immature, gross perceptual-motor modes, fitting him poorly for the fine perceptual-motor

focusing which accompanies many types of cognitive functioning. For example, premature demands for fine, visual discrimination (as in reading) upon undeveloped structures are thought to make progress difficult and induce emotional and/or visual damage to the child (Gesell, 1949; Gesell et al., 1949).

It is also felt that extensive participation in social relations during the early years is essential for the most balanced personal development. Without quarreling with this last view, we believe that a few minutes to an hour a day spent with books and related intellectual stimulation is far from unbalancing. It may decidedly enrich development through augmenting knowledge and advancing environmental mastery.

Because of the dangers imagined it is logical that specific tests of these hypotheses have been rare. In addition, these fears have undoubtedly discouraged research on early cognitive learning per se, despite the fact that what little evidence can be mustered contradicts these theories, or is tenuous at best.

In the first place, the excellent adjustment and accomplishments which gifted children have realized (Cox, 1926; Miles, 1954; Terman, 1918, 1925; and many others), suggests the value of intensive early stimulation which apparently all gifted children receive. Furthermore, we have no assurance that this special stimulation may not itself be an indispensable agent in the formation of high abilities.

Secondly, in studies which included medium or low IQ children under 5, who were given some form of lengthy cognitive training, there is no evidence the children suffered ill effects of any kind—including vision —(Brown, 1924; Davidson, 1931; Dawe, 1942; Dubin, 1946; Gesell & Thompson, 1941; Jersild & Bienstock, 1931; McGraw, 1939; Moore & Anderson, 1960; Thompson, 1944; Updegraff, Heiliger, & Learned, 1938; and others). While investigation never has centered on emotions, many of the studies included material relevant to this area (especially, Davidson, 1931; Gesell & Thompson, 1941; McGraw, 1939; Moore & Anderson, 1960; Thompson, 1944). Of the latter studies, all except Gesell and Thompson (1941) are inclined to attribute many benefits, socioemotional as well as cognitive, directly or indirectly to the stimulation.

Experiments on the nature-nuture issue, as we have observed, were rarely designed either to influence or to trace the kinds of experience encountered during the early years. Only in nursery school programs has some effort been made along these lines and, here, perceptual motor and social skills have been found to predominate. In the few studies that used specifically defined cognitive programs, the effect upon emotional adjustment and social learning appears to have been highly favorable (Carr, 1938; Davidson, 1931; Peters & McElwee, 1944; Thompson, 1944). Thompson (1944) furnished 11 children with a cautious program of cognitive guidance in nursery school activities, compared with minimum guidance for the matched controls. IQs were not specified, but apparently were not far above average. At the end of one school year the experimental children scored significantly in the following traits of social-personal development over their controls: ascendance, constructiveness (when faced with possible failure), social participation, and leadership ability. No change was found in the

proportion of "nervous habits," however. Although both groups gained in IQ scores, the experimental group made slightly larger gains (difference, $p < .10$). This small difference may be ascribed to the fact that the type of activities were identical for both experimental and control children. More important, guidance techniques consisted only of increased personal attention, indirect methods, and some organizing of play materials. Verbal guidance techniques were largely excluded.

Peters and McElwee (1944) found, moreover, that their 6 socially deprived 3-year-olds of low IQ appeared to benefit heavily in social and emotional functioning and suffer no harm from 8 months of organized cognitive stimulation. They gained 42 points in social quotient on the Vineland Social Maturity Scale and increased on Merrill-Palmer Personality ratings. Since controls were omitted, however, these results and other gains reported in self-confidence and initiative in attacking new problems should be eyed with caution.

Evidence of a more negative sort occasionally has marred this generally satisfactory picture. It will be remembered that Welch (1940b) encountered some motivational resistance when he endeavored to teach genus-species relations to 12–20 month old children. It is difficult to draw conclusions, however, since Welch supplies only spotty details. As noted earlier, Welch's methods may sometimes have been inflexible and he failed to separate experimental methods from subject matter. Moreover, his subjects often learned the relevant concepts. It may also be of consequence that Welch does not mention emotional difficulties as an important or recurrent problem in any of his extensive experimental work with preschool children.

There is, perhaps, only one other study directly concerned with the emotional problems connected with preschool cognitive learning (Fowler, in press). In Fowler's investigation of early reading with Velia, his 2-year-old daughter, he observed a number of signs of emotional maladjustment toward the end of the training. It was not possible to determine, however, to what extent these may have been due to: (*a*) cumulative pressures which may have arisen from the reading stimulation per se; (*b*) a known, difficult, and concurrent nursery school conflict experience (the child was one of only two 2.5-year-old-children in a group of seven, active 3- to 4-year-olds, all at least 7 months older); or (*c*) other factors, such as faulty methods of teaching, singly or in combination with the first factors. It is noteworthy that the appearance of Velia's only important and persisting emotional problems coincided to the week with nursery school attendance. The difficulties followed 7 months of adequate and improving social adjustment and motivations for the training.

Velia has remained under observation for the ensuing 5.5 years. Essential recovery was disclosed (after some months) from earlier emotional troubles. Moderately good social adjustment has been maintained since that time. Interest and achievement in reading have been very high and the child also follows a broad pattern of cognitive and phsyical activities.

It is also true that studies of bright children, who were highly stimulated at an early age, have uncovered a small proportion who experienced some disturbance in personality functioning. Cases have been concen-

trated in the extremely high IQ subgroup (e.g., Hollingworth, 1942). Significantly, problems have generally appeared to stem from the child's social role difficulties, arising from the manner in which society has tended to evaluate a child of this caliber—viz., "egghead"—(Hollingworth, 1926, 1936, 1942; Miles, 1954; Root, 1921; Terman, 1925; Terman & Oden, 1940a, 1940b, 1947; Witty, 1930, 1940). Occasionally there is evidence that role adjustment problems of this type may not have been the sole source of disturbance (e.g., Barlow, 1951; Dolbear, 1912; Hollingworth, 1926, 1936, 1942; Jordan, 1933; Root, 1921). Post hoc case records have not proved decisive on these points, however. The concurrent appearance of signs of faulty child rearing (parental ambivalence, overindulgence, etc.) or pressuring methods of training have precluded judgment of the effects of cognitive stimulation as such.

Historically, as we have seen, the severe conditions in early infant schools probably brought extensive emotional problems. But where conditions were less rigorous, the socio-emotional consequences may even have been highly positive (cf. Rusk, 1933). This contrast supplies some evidence that defective methods, rather than early stimulation, may endanger the child's emotions.

Correlations between learning difficulties and personality malfunctioning often have been reported in the field of educational research (Anderson & Dearborn, 1952; Gann, 1945; Gates, 1941; Milner, 1951; Missildine, 1946; Robinson, 1946; Smith, 1955; and others). Findings have been complex and inconsistent, however, and the direction of antecedent-consequent relations often has remained uncertain. This has led Smith (1955), among others to conclude that reading problems, for example, and emotional maladjustment both arise from a common constellation of causes. While there is some evidence that coercive *methods* may be harmful (e.g., Missildine, 1946), the indictment is unclear with respect to the role of preschool stimulation. Actually, data from educational sources mostly are concerned with elementary school age children and are of little concern here.

Certain experiments in discrimination learning (Razran, 1933), i.e., where differences between CSs are gradually reduced below threshold, have produced emotional disturbances in animals. Other experiments, employing a frustration-aggression hypothesis (Barker, Dembo, & Lewin, 1941; Dembo, 1931; Fajans, 1933), have resulted in temporary frustration reactions in children. These studies may have a narrow range of application because in both types of experiments there were actually *no* solutions available for the problems as they were defined. Nevertheless, the children often became markedly frustrated when confronted with complex stimuli *apparently* open to solution (the frustration-aggression hypothesis problems). This may be analogous to the problem the very young child faces when presented with complex cognitive stimuli above his comprehension level, but which the adult presents *as if* the child *should* be able to grasp them. On the other hand, is this problem essentially different from the hazards of presenting stimulation at *any* age which is improperly graded and paced for the child's level?

We wonder, in short, whether our modern anxiety over the damage childhood cognitive stimulation *may* induce is sufficiently anchored in

reality. In the probably well-founded criticisms of severe methods formerly (and perhaps even now occasionally) used, was there any reason to assail the process of early cognitive instruction per se? Is it possible that reformist zeal, fed liberally by the discoveries of Freud and others, may have resulted in methods and conditions being profoundly confused with subject matter, that is, cognitive material as such? Research to date, although requiring much extension, appears to harmonize very well with such an interpretation.

Discussion and Summary

This critical survey of selected literature on cognitive learning in early childhood has been made in order to gain perspective on certain crucial but widely neglected research problems. Neglect of these problems has resulted in a stress on genetic factors in early cognitive development. Correspondingly, this has been at the expense of visualizing the scope and complexity of learning realizable during the intial phases of development.

Traditionally, there appear to have been two major viewpoints explaining processes of development, and to account for the protracted course children go through to acquire complex knowledge. The first view fixes on concepts derived from biology. Under this view, intelligence and various abilities are postulated as inherited. They emerge through a process of unfolding along a growth continuum in several ordered stages of maturation. Modification of this innately determined patterning by means of environmental circumstances is placed in secondary position.

In research, this view has led to a concentration on empirical studies organized cross-sectionally for collecting normative data. For the most part, these norms have been linked sequentially to chronological age levels (e.g., MA or any age-trait behavior). The use of longitudinal studies has been, logically, an important additional derivative of this view. But a maturationally oriented developmental framework has so dominated long range investigations made under its jurisdiction, as to cloud evidence which might have led to alternate conclusions. In addition, there are other important research errors and orientations which have tended to feed this bias. These include the frequent omission of adequate controls; the experimental fusion of variables; an emphasis on sensory-motor and social-emotional development to the relative exclusion of complex, perceptual-cognitive processes; and, above all, the simple omission of (antecedent) experiential data.

An important group of better controlled studies has probed the maturation versus learning issue. These studies have, in the main, continued subordinate to maturationally oriented hypotheses; have failed to separate general experience from maturation; and have too often designed training programs with only simple material and/or have covered too short a time span. These limitations have aborted opportunities for impressive gains to accrue in cognitive learning.

The second more or less opposing view, while according a greater role to experience, has generally been dominated by a behavioristic outlook. In its concern for dealing with operationally definable processes, this outlook has only recently begun to divest itself of a molecular focus which has relegated complex conceptual

processes to the second-class status of "intervening variables." This outlook also has generated a situational focus abstracted from the molar life situation, history, and developmental status of the organism.

Preoccupation with precision and accurate measurement has induced many behavioral researchers to cling to high control, animal experimentation of the laboratory. This has meant a comparative neglect of experimentation on learning in children. The less frequent investigation of children has been much confined to correlational or cross-sectional study of a few isolated components of behavior. Learning processes, where studied, have embraced problems whose solution depends only upon a few simple operations acquired over a restricted number of trials. Little attention has been directed toward longitudinal work on the antecedent-consequent relations of basic cognitive dimensions.

The net effect of the two frameworks combined has been to retard the development of interest in cognitive learning in young children. There have been, however, other serious brakes upon the growth of such an interest. Experimental work can be expensive. Longitudinal studies of cognitive learning processes are likely to demand heavy outlays of time, energy, and resources. The detailed and costly nature of the necessary planning, observations, and teaching energies is multiplied by the intricacy of processes involved in acquiring knowledge. Reading a language, number calculation, playing a musical instrument, and conceptualizing physical causality are all processes organized in terms of complex systems of interrelated verbal symbols and concepts. Learning such systems inevitably becomes a long-term, increasingly complex, and cumulative process. Each series of steps is integrally related to and founded on lower orders of information. As a result, progress demands that material be broken into simplified components and presented systematically, step-by-step in a long, shallow gradient.

Consider that even older children and adults are likely to require prolonged time spans to make substantial headway in learning any complex cognitive system. Thus, the presumed inability of the preschool child to learn large blocks of knowledge may well be more apparent than real. Possibly it is more our failure to teach the child systematically in these areas than it is his inability to learn. The promising results in the few longitudinal training studies of this kind support this conclusion.

There are of course additional conditions which may contribute to the young child's difficulty with complex cognitive learning. Among these are characteristics which may inhere in the learning process itself during the initial stages of life. Something of the nature of this process has been adumbrated by learning theorists, notably, Hebb (1949) and Harlow (1949), and conceptualized in other ways by Piaget (1952). At birth, the infant, virtually lacking any knowledge at all, must spend an "apprentice" phase acquiring the most elementary foundation discriminations and generalizations on the nature of the physical and social world. These primary concepts are perhaps the most difficult and slowest to come by. This is because the infant possesses no general frames of reference to serve as guides or conceptual leverages for learning. Stated in another way, the neonate and child for some time is, essentially, learning the process of

how to learn; he is "learning to learn" or is acquiring directional learning sets. In this manner, what to an adult are tiny and insignificant steps in learning various systems are, to the very young child, probably giant strides.

The early years may hold special problems for acquiring knowledge. But unless efforts to explore cognitive learning in young children are greatly multiplied, we shall continue to know little about them. Fortunately, signs of interest in a perceptual-cognitive framework, if not in cognitive learning, have been appearing more often recently in writings on child development. Examples may be found in the texts of Thompson (1952) and, particularly, of Baldwin (1955). The new handbook of research methods (Mussen, 1960) labels an entire section "cognitive processes." The ideas of a number of psychodynamic (e.g., Isaacs, 1945; Sullivan, 1953), learning (Hebb, 1949; Harlow, 1949), and perceptual-cognitive theorists (e.g., Piaget, 1952; Solley & Murphy, 1960; Werner, 1957) have also in some ways bridged traditional gaps existing among developmental, learning, perceptual, cognitive, and motivational theories of behavior. However, much remains to be elaborated. More important, to date little of this theory construction seems to have stimulated corresponding research activity on long-term cognitive learning in child development.

Much if not most of the energy in child psychology and development in late years has been concentrated on the child's personality, perceptual motor, and socioemotional functioning and development. Originating primarily as a reaction to historically inadequate and stringent methods, fears have generalized to encompass early cognitive learning per se as intrinsically hazardous to development. As legitimate areas of study, the contributions of studies on perceptual-motor and socioemotional problems are obvious. But in the field of child guidance, interest in these areas has come to permeate and dominate work in child development almost to the exclusion of work on cognitive learning. In harking constantly to the dangers of premature cognitive training, the image of the "happy," socially adjusted child has tended to expunge the image of the thoughtful and intellectually educated child. Inevitably, in this atmosphere, research (and education) in cognition has lagged badly, especially since the 1930s, not only for the early years of childhood but for all ages.

Even prior to the more recent era, however, very little careful research was done on early cognitive learning. As historical evidence shows, most studies have comprised the work of those "beyond the pale" of formal psychology. Yet, taken collectively, the findings are so provocative as to make us entertain hopes that many, if not all, children can and indeed should be offered much more cognitive stimulation than they have been generally receiving.

There is, however, a further problem, at once a derivative of and an important contributor to the failure to undertake work on cognitive learning. Few systematic methods have been devised for educating young children, especially in complicated subject matter. We have in mind methods for simplifying and organizing the presentation of cognitive stimuli. Equally important, methods must be sufficiently flexible and play oriented to be adaptable to the primary learning levels and per-

sonality organization characteristic of the infant and young child.

The advantages of utilizing the now relatively untapped "preschool" years for cognitive education are of course manifest. Most obvious, is the availability of more years of childhood to absorb the increasingly complex technology of modern society, a technology already requiring many of the more productive years of development to acquire. A second is the less evident but more crucial possibility that conceptual learning sets, habit patterns, and interest areas, may well be more favorably established at early than at later stages of the developmental cycle. Moreover, there may be problems inherent in allowing long-term sets and the accumulation of knowledge in one area to take precedent over learning in another. Conceivably, to establish prior sets in one style (e.g., impulsive, concrete, or gross motor orientations) may even strongly inhibit later attempts to learn in other directions (e.g., problem solving, abstract, or verbal orientations). As a minimum, cognitive orientations might preferably be established early in development, concomitant with other approaches.

What of norms? Will research and educational programs of this kind eliminate the need for norms? The answer depends upon what circumstances are taken into account. Yes, if we are thinking of norms for cognitive development as presently measured with little relation to differences in children's life histories. No, if new ones are established or present ones modified on the basis of serious probes of the cumulative limits of cognitive learning during the early years.

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RADIATION RESEARCH IN PSYCHOLOGY: AN ANALYSIS OF TECHNIQUES IN MAZE EXPERIMENTATION

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The past 10 years of work, involving the study of the effects of X radiation upon the learning and retention of the rat has introduced many variables which are in need of careful reexamination. The experimental findings have been fairly consistent in showing that the unborn irradiated organism is more drastically affected in its learning ability than is the postnatally irradiated subject (Furchtgott, Echols, & Openshaw, 1958; Kaplan & Harris, 1957; Kaplan, Tait, Wall, & Payne, 1951; Levinson, 1952; Levinson, 1960; McCutchan, 1957). Likewise, it has been shown that the learning ability of the neonate is more adversely affected by X radiation than is the adult rat (Kaplan, Tait, Wall, & Payne, 1951; Levinson & Zeigler, 1959; Tait, Wall, Balmuth, & Kaplan, 1952).

Several learning instruments have been used to study these behavioral effects of X ray. Among these, at least six different mazes (Arnold, 1952; Blair, 1958; Blair & Arnold, 1956; Fields, 1957; Fowler, 1957; Furchtgott, 1951; Hayes, 1957; Levinson, 1952), operant conditioning equipment (Kaplan, 1960; Melching, 1957), and a variety of field study and psychomotor tasks have been employed (Furchtgott & Echols, 1958; Hayes, 1957). It is the purpose of this paper to isolate one of the methods of study covered by various authors during the decade to point out the weaknesses and capabilities of psychologists in answering some of the questions in this field which are of vital concern to radiobiologists.

In the interest of posing the problem, the data obtained from studies of irradiated rats, wherein the Lashley III maze has been used, will be subjected to a methodological analysis. This maze, principally because it has been efficient in showing differential effects upon learning as related to amount of cortical insult (Lashley, 1929), has been used by workers studying effects of radiation upon learning. In employing the Lashley III maze, it generally has been accepted that the hypothesis of deleterious effects of X radiation upon brain function would be supported should learning deficits be demonstrated.

The Scope of the Problem

Radiation has been shown to have an adverse effect upon learning of the albino rat under certain conditions. It is clear that the interrelationships between age at time of radiation, age at time of testing, dose rate, magnitude of dose, are all important factors in the amount of learning deficit found. It has also been clearly shown that there are marked individual differences in resistance to radiation, which implies that samples of sufficient size are necessary in order to make meaningful generalizations from data. In order to study even a few of these factors, experimenters in the average university laboratory find it extremely difficult to conduct their experiments without confronting difficulties such as inadequate space, insufficient storage facilities for ample numbers of

experimental subjects, shortages of man power, time, and finances. For example, in light of the importance of studying animals which have been radiated in utero and are not tested until 400 or 500 days of age, space must be available for storing the animals for that period of time. Again, to allow for adequate samples of subjects radiated with five doses at 10 different pre- and postnatal periods, one must employ very large populations of subjects.

The answer to the problem has been attempted, in part, by independent workers in various laboratories who have attacked different aspects of the same problem. Levinson (1952), Levinson and Zeigler (1959), Furchtgott, Echols and Openshaw (1958), Tait et al. (1952), Kaplan et al. (1951), Kaplan (1960), and Levinson (1960) all have explored different aspects of effects of radiation on performance. Their work has extended over a period from 1950 to 1960. As can be seen in Table 1, many of the variables isolated as

TABLE 1

PRE- AND POSTNATAL RADIATION STUDIES BETWEEN 1950 AND 1960

PRENATAL: Age at Time of Radiation (Days)

R	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
10								5⁻													
25		3″						13⁻													
50						7″	7⁻	15⁻			4″	6″									
90														16⁺							
100								3⁻6″						10°				11°			
150								12⁻													
180														16⁺							
200	3⁻													11°				4°			
250																					
300											4°		4°	2°	4°	6°	4°	7°	4°		
350																					
375													8°			16°					
400																					
450															3°		8°		4°		
500																					
550																					
600											4°		4°		4°		4°		4°		

POSTNATAL:

R	1	2	4	6	8	14	18	24	41–105
90									8⁻
150		5°	5°	5°	5°	5°	5°	5°	
180									7⁻
200	13°								
225		20°	20°	20°					
250		3°	5°	5°	5°	3°	5°	5°	
275		20°	20°	20°					
300	11°								
350		3°	3°	5°			5°		
360									15⁻
600									16⁻

Note.—Age of *N* subjects at beginning of study: ⁺ 30 days, ° 45 days, ⁻ 90 days, ″ 400 days.

relevant have been investigated, and it would seem that the combined efforts of these authors should have begun to provide many answers to the problems under question. In some ways, there is no doubt that this is so. There is consistency among the findings to a remarkable degree. Yet, in the interest of better scientific methodology, it is important to present the many limiting factors existing in the accumulated data which make cross comparisons and generalizations difficult, if not impossible, without much additional experimentation.

The Literature Under Consideration

Prenatal Studies. From Table 1, it is seen that several papers have appeared reporting that subjects have been X-radiated in utero. These studies have received much attention from scientists studying radiation effects upon the nervous system, particularly in view of the histological analyses that call attention to the times throughout the gestation period when specific organs and organ systems are peculiarly sensitive to radiation damage (Hicks, 1950; Hicks, 1953; Rugh, 1960).

These experiments have all tended to support the position that the second week of gestation reveals the most marked deficits in learning,with the thirteenth day being one of the most critical periods (Levinson, 1952; Tait et al., 1952). More recent studies, however, have pointed to the fact that the sixth and seventh day may be even more sensitive to radiation damage, in terms of impaired learning, provided the subject is tested at a later age in life than that usually studied by most experimenters (Kaplan, 1960).

Postnatal Studies. Rats have been radiated from the first day post partum through 100 days of age and then tested for learning ability in the Lashley III. In general, the Bergonie Tribondeau law which states, in effect, the younger the tissue the greater its sensitivity to radiation insult (Ellinger, 1946), has been sustained by the experimental findings. Levinson and Zeigler (1959) have found that the rats X-rayed on the first 2–4 days are less efficient learners than those radiated at 24 days of age. And Kaplan and Harris (1957) have shown that the 100-day-old radiated rat will not be impaired by a 100 r.–200 r. dose. Levinson and Zeigler (1959) and Furchtgott et al. (1958) have used these dose levels on younger animals and obtained results showing impairment of learning. Kaplan and Harris have shown it requires an exceptionally large dose, (600 r.), to impair the learning of the 100-day-old radiated rat.

Procedural Differences

The primary problem in analyzing these findings rests on the variation in procedures. Maze and training differences in the various experiments, criteria for evaluation of results, and radiation procedures all involve differences which may possibly affect the use of the data for purposes of comparing and amplifying work of individual authors.

The Maze. Since Lashley has provided only a limited description of his maze (Lashley, 1929), the various workers in this radio-behavioral field have employed modifications of the original without recourse to a standardized and universally agreed upon version of that instrument. Furchtgott et al. (1958) described a maze having a linoleum floor, painted grey, and a hardware cloth top. The mazes of Levinson (1952) and Tait et al. (1952) differ in the length of the entrance and exit alleys, and neither

group of authors states whether their mazes had floors and top similar to that of Furchtgott. Kaplan (1960) used a maze 12 inches in height, painted black; Levinson's maze was 3½ inches in height and was unpainted. Kaplan also employed retrace gates while the other workers (Furchtgott et al., 1958; Levinson, 1952; Levinson, 1960) did not make mention of this innovation.

The Straightaway for Preliminary Training. While Furchtgott used a 3-foot alley runway (Furchtgott et al., 1952), Levinson employed the Lashley I maze (dimensions not given) for preliminary training (Levinson, 1952). Kaplan et al. (1951) and Tait et al. (1952) used a 4-foot alley runway, and Kaplan (1960) in other studies used a 6-foot alley runway.

Preliminary Training and Testing Procedures: Food Reward and Implied Differences in Motivation. Workers have differed in amount of food deprivation employed. Kaplan (1960) reported a 23½-hour deprivation schedule. Furchtgott et al. (1958) reported a 22-hour deprivation, while Levinson (1952), in one report did not include mention of the deprivation period, and in another (1960), mentioned a 23-hour deprivation schedule.

For food reward, mention has been made of bran pellets scattered on the floor (Furchtgott et al., 1958), three moistened Purina lab pellets (Kaplan, 1960), and a moistened Purina mash made into a pellet (Levinson, 1960). Some workers allowed 30 seconds for the rat to eat at the end of the runway (Kaplan et al., 1951; Tait et al., 1952), several did not mention time allowed for eating (Levinson, 1952; Levinson, 1960), while others allowed 10 seconds for eating at the end of the runway (Hicks, 1953).

Variation in daily feeding for maintaining body weight and constant motivation also has been reported. Furchtgott et al. (1958) fed their subjects 1 hour per day, 30–60 minutes after the run. Others have not mentioned the feeding schedule (Levinson, 1952; Levinson, 1960; Tait et al., 1952).

Preliminary Training. Some workers reported all subjects are handled several days before straightaway training is begun (Kaplan, 1960). Others did not mention handling procedures (Furchtgott et al., 1958; Levinson, 1952). One report described preliminary adaptation as simply a 3-day period in a single unit straight alley (Levinson, 1960). Two trials per day for 6 days have been employed as a training method by other authors (Kaplan, 1960). Levinson (1952) reported training her subjects daily (number of trials per day not stated) until they had run three consecutive trials in 20 seconds. Tait et al. (1952) allowed three trials per day for 3 days with no time criteria mentioned. Furchtgott reported keeping each subject in the runway 10 minutes daily for 7 days (Furchtgott et al., 1958).

Hence, for preliminary training, it can be seen that degree of docility arising from differences in handling, and criterion of readiness both become factors contributing to an incomparability between the studies. Learning rates subsequent to this training undoubtedly are a function, in part, of the levels of motivation attained by each rat performing under the requirements established for its respective training procedure.

Training and Evaluation. The experiments under scrutiny present five different procedures for testing the subjects in the Lashley III: (*a*) in one experiment (Furchtgott et al., 1958) rats were given two trials per day the first day, three trials per day the next 3 days, and five trials per

day for the last 2 days; (*b*) in another set of experiments (Levinson, 1952) rats were given five trials per day to a criterion of two out of three errorless trials in 10 seconds; (*c*) in the third group of studies (Tait et al., 1952), subjects were given one trial per day, 6 days per week. In some of these, retrace gates were employed; in others, they were not. The criterion of mastery for these studies was four out of five errorless trials, time of running not considered. (*d*) In a fourth group of studies (Kaplan, 1960), rats were given one trial per day, 7 days per week to a criterion of four out of five errorless trials. In this group of studies, running time was not considered in the criterion of mastery.

Definitions of Errors. Some authors have scored nonretrace and retrace errors involving full-body-length entry (Levinson, 1952). Others (Kaplan 1960) have included full body, $\frac{3}{4}$ body, $\frac{1}{2}$ body length forward and retrace errors and also "hesitation errors." Kaplan has utilized all of these errors in arriving at an "errorless trial" which obviously represents a more stringent criterion than only a body length error.

For the most part, all seem to be in agreement on measures of time scores, i.e., from time of leaving the starting box to entry into the goal box.

Radiation Differences. The differences between studies cited here refer to differences involving comparative psychology methodology. An equally serious variability in radiation procedures prevails (Table 2).

It has been shown that with monkeys, a rate of 15 r/min (Kaplan & Gentry, 1953) as compared with 1,000 r/min (Kaplan, Melching, Reid, Rothermel, & Johnson, 1960) has a markedly different effect upon behavior. Unless relative biological effects (RBE) can be equated, comparisons of maze behavioral studies will be affected adversely (Glasser, Quimby, Taylor, & Weatherwax, 1952; Pickering & Hekhuis, 1960). (For example, it has to be established that the differences in rate which range from 10 r/min to 116 r/min produce comparable biological effects with dose held constant.) The radiobiologists and physicists have pointed out that there is a markedly different quality to the radiations produced by X-ray machines of highly different voltages[1] (Glasser et al., 1952; Pickering & Hekhuis, 1960; Rugh, 1960). The target distances, reported in the experiments under consideration, vary between 50 and 91 centimeters. Variations in dis-

[1] "Regarding the enclosed data [Table 2], a number of things must be said.

1. The KVP variations will affect the quality of radiation, and consequently its penetrability. For instance, a rough estimate would be that at 80 KVP the penetration to a gravid rat uterus would be about 20 per cent less than with 250 KVP. This is a very rough estimate. The way to check is with a phantom.

2. The amperage has nothing to do with the quality of radiation and if a Victoreen dosimeter were used to determine roentgens, at a specific point, this would not be appreciably altered by altering the amperage.

3. In several instances no mention is made of filtration, either added filtration or inherent filtration of the x-ray tube. This is a serious omission. If no filtration is used at least that of the tube should be mentioned.

4. There is a trend now which will soon become insistent that radiation be expressed in rads, not roentgens. This refers to absorbed dose and not air dose, and is generally somewhat less because of attenuation. Roentgens are air dose measurements, generally, but in biology we are interested in absorbed dose.

Thus, some of these data are useless because they are not reproducible. [The data being insufficient.] Further, the data are not comparable when the KVP range is from 80 to 250. The data might be more comparable if single cells were involved, in a mono-layer of cells, but certainly not in a rat." (R. Rugh, personal communication, October 26, 1960.

TABLE 2

DOSIMETRY DIFFERENCES BETWEEN EXPERIMENTS

Rate	Dose	Target distance	KVP	Milli-amperes	Filtration	Reference
41/min ±0.82	100 200 300	50 cm.	170	10	not reported	Furchtgott, Echols, & Openshaw, 1958
50/min	50 100 150 200 upper and lower tubes	67 cm.	180	30	.28 Cu .50 Al HVL .6 Cu	Kaplan, 1960
25/ min	25 upper tube only	69 cm.	180	30	.28 Cu .50 Al HVL .6	
10/min	10 upper tube only	91 cm.	180	30	.5 Cu .5 Al HVL .8	
30/min	0 90 180 360 600	91 cm.	250	15	.5 Cu 1.0 Al	Kaplan, Tait, Wall, & Payne, 1951
116/min	0 300 375 450 600	12 in.	80	4	not reported	Levinson, 1952
6.0/min to 6.2/min	0 150 350	1 meter	200	10	1.0 Al .5 Cu	Levinson & Zeigler, 1959
30/min	0 90 180 360	91 cm.	250	15	.5 Cu 1.0 Al	Tait, Wall, Balmuth, & Kaplan, 1952

tance may not be as significant as the varying amperage of the machines (4 ma.–30 ma.), but it is still important to recognize that the ionizing capability of the 80 KVP X-ray machine that Levinson (1952) employed to produce her behavioral findings with rats given 300 r., may be different from that of the 170 KVP machine used by Furchtgott et al. (1958), or the 250 KVP machine used by Tait et al. (1952). Both of the latter experiments gave approximately the same total body dose but with different amperage, rate, and target distance.

Some workers report how they compute target distances; others do not. Some report the filtration included in the radiation source; others do not. Some employ phantoms for determining relative biological dos-

age given; some measure dosage in air. Some report deviation of measurement; others do not.

Discussion

The implications of this analysis cannot be ignored. In spite of the fact that each study has employed normal control subjects and has provided needed information on the problems investigated, much valuable cross referencing has been limited because of the differences in procedures employed. With so many questions yet unanswered, it would seem valuable to the profession if those working in the field could agree to standardize some of these experimental conditions while permitting latitude in the study of the particular problems not contingent upon this standardization.

If the Lashley III maze is to be used for radiation study, it is suggested that its characteristics be as constant as possible. Likewise, provided they do not interfere with the goals of the study, it is suggested that the procedures for preliminary training and testing be standardized as to handling, food reward, and measures of learning. The same recommendation is submitted with regard to the employment of X-radiation sources so that the comparability problem may be controlled as far as is practicable. Such a standardization would certainly lead to the acquisition of data which would establish greater validity for the Lashley III maze as an instrument of measurement of radiation effects.

Similar standardization should be established for all other instruments used in radiation studies. Perhaps second to the Lashley III maze, the Tolman-Honzik or Stone multiple T maze is the most extensively employed (Arnold, 1952; Blair, 1959; Blair & Arnold, 1956; Fowler, 1957; Harris, 1956; Harris & Kaplan, 1957). Experimental studies using this maze should be examined for possible adjustment of standardizable factors. The same arguments apply to the procedures under study by workers using operant equipment. In the operant field, perhaps, it is premature to make such an effort, since the operational techniques are still in process of being established. Still, since several workers have been using this technique in studying learning after radiation (Kaplan, 1960; Melching, 1957) their attention is called to the necessity for standardizing apparatus and procedures here.

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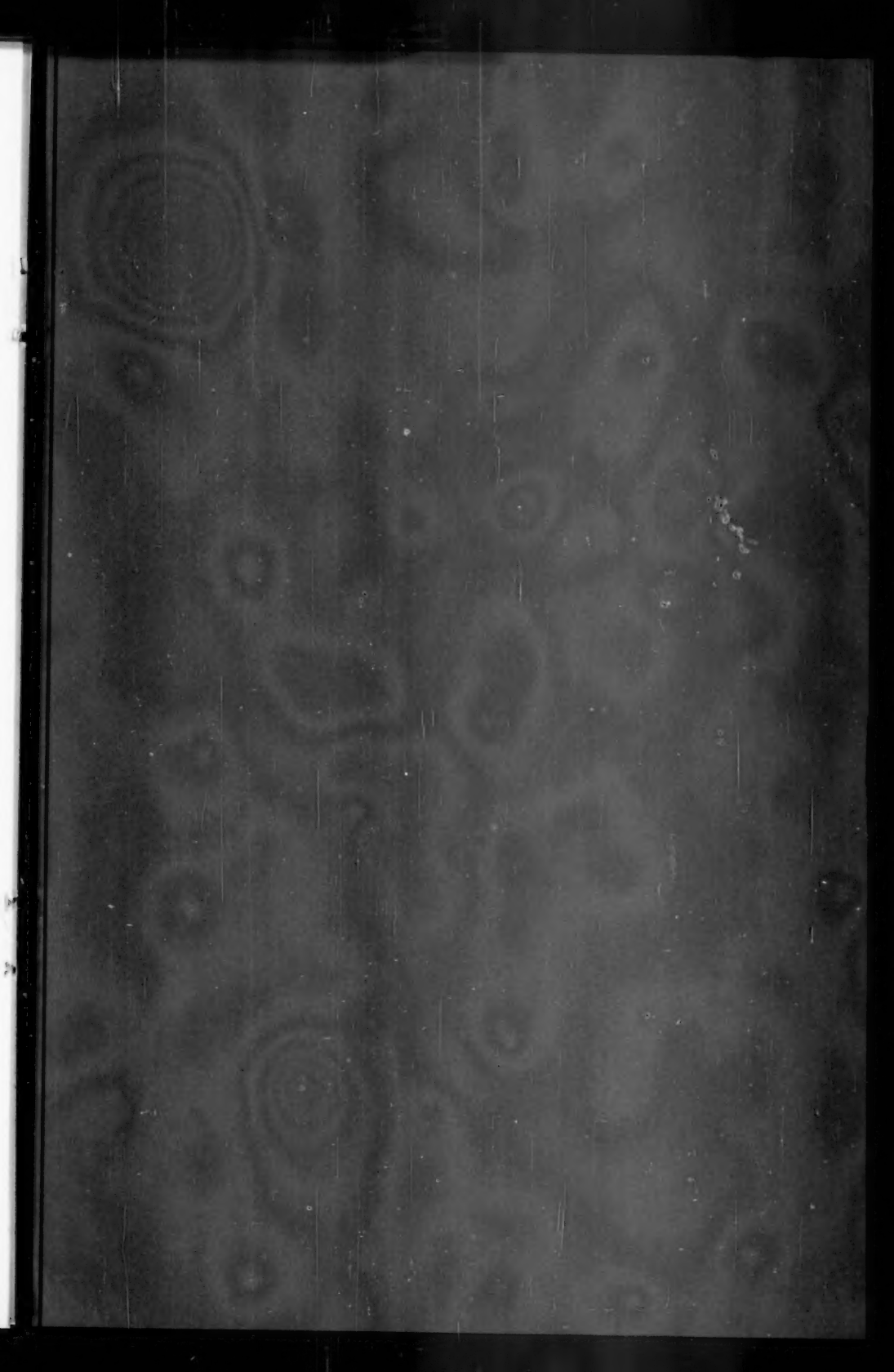
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